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ASSESSMENT OF ENVIRONMENTAL CONTAMINATION EXPLORATORY STAGE TOOELE ARMY DEPOT TOOELE, UTAH

VOLUME I FINAL REPORT

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ASSESSMENT OF ENVIRONMENTAL CONTAMINATION VOL

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VOLUME I FINAL REPORT

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This report documents the Exploratory Stage environmental survey conducted at the Tooele Army Depot, Tooele, Utah, by Ertec, Inc., Long Beach, California. The objective of the survey was to determine whether contaminants are present in a vector crossing the installation boundary or are present at a source where the contaminants have a potential to cross the boundary. Phase I of the survey consisted of a review and assessment of existing data to define potential sources of contamination and potential contaminants capable of migrating by surface water, groundwater, air, biota, or man-made means. This assessment

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including a hazard ranking system, defined sites for further study. Phase II of the survey comprised the sampling of soil, sediment, surface water and groundwater and the analyses for contaminants identified in Phase I. Contamination and the migration of contaminants have been found to be minimal at the Depot.. Three areas have been found where contaminants have the potential to migrate or are migrating across Depot boundaries or towards Depot potable water supply wells: the Headquarters Area consisting of Industrial Waste Pond, outfalls, and the Sewage Lagoon; and the TNT Washout Ponds in the North Area of the Depot; and area-wide arsenic contamination in the South Area of the Depot. Results, conclusions, and recommendations are included in the report.

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1.0 EXECUTIVE SUMMARY

This report documents the Exploratory Stage environmental survey conducted at the Tooele Army Depot (TEAD), Tooele, Utah, as described by Contract Number DAAG49-81-C-0192 issued by the Procurement Division, TEAD, under direction of the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). The objective of this survey is to determine whether contaminants are present in a vector crossing the installation boundary or are present at a source where the contaminants have a potential to cross the boundary.

The TEAD consists of two separate areas, the North Area, approximately 39 square miles located in Tooele Valley, and the South Area, approximately 30 square miles located in Rush Valley. Ertec's assessment of the contamination potential for approximately 50 sources in the two areas was derived from information obtained from 7 existing wells, 24 new wells and bore holes, 9 surficial soil and sediment samples, and 6 surface-water samples.

The approach to completing the assessment consisted of two phases. Phase I utilized existing data and preliminary site visits to determine sites having the greatest potential to contaminate the subsurface and surface environments at TEAD. This phase resulted in a matrix that relates approximately 100 potential contaminants to 86 potential sources of contamination. This matrix was utilized in conjunction with a hazard ranking system to select sites for field investigation. Phase I was accomplished during the period October 1981 to December 1981. Phase II comprised the sampling of soil, sediment and water and the analyses for contaminants identified in the contamination matrix for these sites. Phase II was accomplished during the period January 1982 to July 1982.

The techniques and protocols used to collect and analyze samples, install monitoring wells, and obtain magnetic, gravity, seismic, and resistivity results for the geophysical surveys, were carefully designed to provide reliable and accurate information. Quality assurance procedures ensured the accuracy and reliability of the collected data. Safety procedures designed by Ertec and reviewed by USATHAMA and the TEAD Safety Division were followed by all Ertec and subcontractor employees while engaged in all project-related work.

Because of the unexpected difficulty in drilling in the North Area, the problems associated with winter field conditions, and an attempt to provide the maximum information in the most cost-effective manner, modifications have been made in the original field program. These modifications, approved by USATHAMA, included revision of the field program, chemical analysis methodology, and the data management program.

The field program began with geophysical surveys in the North Area after discovery of what was suspected to be a buried bedrock ridge running through the area. This formation would have a serious impact on the movement of ground water and contaminants from such sources as the Industrial Waste Pond, the Sewage Lagoon, and the TNT Washout Area. A preliminary study using a gravity survey was designed and conducted as the most cost effective procedure for obtaining verification of the hypothesized ridge. Results indicated a ridge was indeed present and very likely would affect ground-water movement, particularly in the vicinity of the Industrial Waste Pond. Consequently, seismic refraction and electrical resistivity studies were designed to "fine tune" the gravity survey, determine the subsurface structure of the bedrock ridge, and provide hydrogeological information in the area. Prior to the actual field seismic program, a blast test was required by the Depot Safety Division and by the Ammunition Surveillance Division because of concerns about ammunition stored in some of the igloos. Results of the blast test were used to modify the design of the seismic study.

The drilling operations commenced in January and lasted into June. Magnetic surveys were used to clear sites for unexploded ordnance and buried drums prior to drilling. Ten wells or borings were drilled in the North Area and 14 drilled in the South Area. Soil, sediment, surface-water and ground-water samples were collected and analyzed during this period. The evaluation of data obtained from drilling, sampling, and chemical analyses resulted in 1) definition of the occurrence of ground water including perched zones, mounds, discharge and recharge areas, regional, and local hydrogeology, 2) definition of contaminants discovered at each sampling site, and 3) determination of problem areas where contaminants have the potential to migrate or are migrating off the Depot.

All chemical analyses for contaminants identified with the contamination matrix were performed by the Utah Biomedical Testing Laboratory (UBTL) in Salt Lake City. Under this project, UBTL was certified for both qualitative screening of contaminants and semi-quantitative analyses. UBTL developed new and adapted existing analytical methods during this project. Semi-quantitative values are included in this report for samples taken during Phase II. Because of the method used for extending laboratory certification to the semi-quantitative range, information has been obtained that can be used to estimate not only the presence, but also the degree of contamination, at a cost savings to the government and without compromising the reliability of the results.

Ertec has defined three areas in which contamination of the ground water has occurred - two in the North Area, and one in the South Area. Ground-water contamination in the Headquarters Area of the North Area is caused by seepage of contaminated water from two sources, the Industrial Waste Pond and the Sewage Lagoon. The Industrial Waste Pond has caused the development of a contaminated perched zone. Contaminated ground water from this source has the potential of migrating toward the Depot's north boundary and toward Depot water supply Well 1. The complex hydrogeology of the area has further complicated matters. Bedrock contamination in this area may provide a long-term source of contamination to the regional aquifer. Leakage from the Sewage Lagoon has produced a contaminated ground-water mound. Ground water from this mound has the potential to migrate towards the north boundary and towards Depot water supply wells. Effluent from the outfalls originating in the Maintenance Area in the North Area may contribute significantly to this problem. The time for pollution from these sources to reach the north boundary is on the order of 55 years from the time contaminants first reached the ground-water system.

The second problem area discovered in the North Area occurs at the TNT Washout Ponds/Laundry Effluent Ponds. High levels of explosives have been discharged over an area of unknown extent and have been detected in soil samples to depths of 100 feet. Contamination of the ground water by RDX and by TNT degradation products has occurred by downward percolation of TNT Washout Pond water. Nitrate levels have been found that are as much as six times the EPA

Water Quality Criteria Standards. Flooding of the contaminated area by contaminated laundry effluent provides a continuing mechanism to flush contaminants to the ground water. Travel time for pollution from this source to reach the north boundary is approximately 125 years from the time contaminants first reached the ground-water system.

The South Area is relatively clear of contamination except for high arsenic levels found in the south and southeastern portions of the site. Arsenic levels have been found to be as much as 20 times the EPA Water Quality Criteria Standards along the south boundary, and are undoubtedly migrating off the Depot property to the south. The exact source of the arsenic is not known, but may be from natural arsenic occurrence or from unrecorded Arsenal agent disposal in the Demilitarization Area/Disposal Pits.

All required data from the installation of wells and borings, from the sampling of surface water, ground water, soils and sediment, and from chemical analyses were entered into computer files in the USATHAMA Tier 1 file format.

The lessons learned during this project occurred in two areas, the chemical analysis program and the geotechnical program. Revisions of particular note relating to chemical analysis are 1) HPLC methods for explosives, 2) preservation of NG and PETN samples, and 3) methods to determine the volume and type of liquid required for extracting samples from soils and sediments. Significant lessons learned about the geotechnical aspects of the project include 1) the modification of drilling procedures, practices, and equipment, 2) the value of geophysics as an investigatory tool, and 3) data management retrieval and transmission methods.

The following sections contain the conclusions and recommendations that have been determined for this study.

1.1 CONCLUSIONS

To determine whether toxic or hazardous materials are migrating or have the potential to migrate off Tooele Army Depot property, Ertec has conducted the Exploratory Stage of a contamination survey at the Depot. The results of the Study have been used to 1) detect possible contaminants crossing the boundary, 2) determine if any contaminated areas within the installation are presenting an imminent hazard to the off-post environment or to personnel working on-post, 3) determine background levels of possible contaminants, 4) define general stratigraphical and lithological relationships, and 5) characterize the general hydrologic system. The following conclusions have been determined for this study:

1. Contamination and the migration of contaminants have been found to be minimal at the Tooele Army Depot. Three areas of concern have been located through the collection and analysis of 36 soil and sediment samples and 30 surface- and ground-water samples. These areas are 1) Headquarters Area, consisting of the <u>Industrial Waste Pond</u>, <u>Outfalls</u> and ditches from the Maintenance Area, and the <u>Sewage Lagoon</u>, 2) <u>TNT Washout Ponds</u>/Laundry Ponds Area, and 3) the South <u>Area arsenic problem</u>.

2. A contaminated perched zone exists in the vicinity of the Industrial Waste Pond. Specific contaminants from this source have a high probability of migrating toward the Depot boundary and <u>towards Depot water</u> supply Well 2. Contaminants that exceed EPA standards are arsenic, nickel, chromium and lead. Contaminants that have been found to be anomalously high are zinc, chloride, flouride, phosphate, sodium, 1,2-dichloroethane, trans-1,2-dichloroethene, trichloroethene, and possibly 2,4,6-trinitrotoluene. The travel time of contaminated ground water from this source to the north boundary of the Depot is approximately 55 years from the time contaminants first reached the water table. This source remains active.

3. Contaminated water from the Industrial Waste Pond has probably entered fractures and solution channels in the underlying carbonate bedrock above the regional water table. If this contamination is extensive, it could provide a long-term source of contamination to the alluvial aquifer by slow drainage. The geometry and the impact of this contamination has not been assessed under this Exploratory Stage study.

4. The impact of seepage to the water table of possibly contaminated water from Outfalls B through E remains unknown.

5. A **ground-water mound** has built up beneath the **Sewage Lagoon**. This water **is flowing toward the north Depot boundary** and toward Depot [redacted] supply **Wells 1 and 2.** While no contaminants were found to exceed EPA standards in the one well that taps this perched zone, the [redacted] **nickel and nitrate approach EPA standards.** In addition, anomalously high levels of zinc, chloride, fluoride, sulfate, gross beta, sodium and trichloroethane were found. Travel time for these contaminants to reach the north boundary is on the order of 55 years from the time they first reached the ground-water system.

6. A local perched water table exists below the TNT Washout Pond/Laundry Effluent Pond Area. Seepage of laundry effluent through soils contaminated with explosives from TNT Washout operations is a continuing mechanism for carrying contaminants to the ground water.

7. [redacted] in the regional aquifer [redacted] Ponds is [redacted] such as [redacted], which are as much as six times the EPA and Utah standards. While this ground water is contaminated, it is conservatively estimated that it would take 125 years to reach the north boundary.

8. DNT and TNT have migrated at least 45 feet down through the soil beneath the contaminated area surrounding the TNT Washout Ponds. A slug of RDX has currently migrated to a depth of 100 feet.

9. The areal extent of explosives contamination in the surface soil around the TNT Washout Pond Area has not been determined under this Exploratory Study.

10. No evidence has been found that contamination is being carried past the North Area boundaries by surface water.

11. Based upon the one sampling point installed in an attempt to intercept ground-water flow from the contaminated areas, contaminated ground water is not moving past this portion of the north boundary. All ground-water flow exits the Depot across the north boundary.

12. The South Area is generally clear of contamination except for arsenic.

13. [redacted] water quality standards is present at the [redacted] Area and is [redacted]. The source of this contamination cannot be defined with available data, but [redacted] agents.

1.2 RECOMMENDATIONS

There is substantial evidence that contaminants from four sources are migrating or have the potential to migrate off Depot property and that contaminants are migrating towards Depot water supply wells. To determine specific flow direction, velocity, magnitude and extent of these contaminant plumes, Ertec proposes the following recommendations. Relative priority levels have been established to better clarify the significance or degree of consideration to be given to each recommendation.

1.2.1 First Priority Recommendations

Ertec strongly advises that these first priority recommendations be implemented.

1. Ground-water monitoring program.

   A monitoring program should include sampling of existing wells at the Tooele Army Depot on a semi-annual basis. Analysis should be based on those contaminants found in the ground water above the LOD, in addition to those deemed necessary by state and federal agencies to fulfill the requirements of the Resource Conservation and Recovery Act (RCRA) as described in 40 CFR Parts 260-267. The well system currently established at TEAD should suffice, perhaps with minor modification based upon negotiation with the agencies involved, as a monitoring program "capable of determining the facility's impact on the quality of ground water" underlying the facility (40CFR Part 265.90). In addition, the monitoring system should include proper procedures and techniques for sample collection, sample preservation and shipment, analytical procedures, and chain of custody control. These have been described in detail in Ertec's Technical Plan submitted to USATHAMA in September, 1981.

2. Bacteriological survey.

   The Sewage Lagoon, Well N-4, and existing Wells 1, 2, and 3 in the TEAD North Area should be sampled and analyzed for fecal coliform and other indicator bacteria to determine the migration potential of these constituents. This information is also used to determine the potential impact of the Sewage Lagoon.

3. Nitrogenous compounds study.

   The Sewage Lagoon, Well N-4, and existing Wells 1, 2, and 3 should be sampled and analyzed for nitrates, nitrites, total organic nitrogen, Kjeldahl nitrogen, and ammonia to help determine potential impact of the Sewage Lagoon.

4. Outfalls water balance study.

   Recording gages should be installed to monitor the effluent from outfalls and the amount reaching the Industrial Waste Pond. From this data, a water balance and ground-water mounding calculation should be made to determine the impact of water loss along the ditches to the Industrial Waste Pond. This information should be included in the hydrogeological interpretation of the North Area and the Potentiometric Head Map should be redrawn. This will aid in determining the seriousness of potential impact to existing Well 2. Studies currently being done by the U.S. Army Environmental Hygiene Agency (AEHA) should be incorpored in this study.

1.2.2 Second Priority Recommendations

These recommendations should be followed as part of USATHAMA's Confirmatory Stage for the Tooele Army Depot.

1. Install Proposed Wells 1, 2, and 3.

   These wells (shown in Figure 18) are necessary to provide information on the degree of contamination and shape of the contaminant plumes caused by seepage from the Industrial Waste Pond and Sewage Lagoon. These wells also act as outpost wells for an early warning of contamination approaching existing water supply Wells 1 and 2. Bacteriological and nitrogenous compound sampling and analysis are also recommended for these wells. If a high level of contamination is found in these outpost wells, the Headquarters Area should be re-evaluated for additional study.

2. Sewage lagoon soil samples.

   Two borings, located in the northeast and southeast sides of the sewage lagoon, should be drilled to a depth of approximately 80 feet and sampled for nitrogenous compounds and nickel, to determine the magnitude and extent of contamination of these substances.

3. Install Proposed Wells 4 and 5.

   Two wells should be drilled to the north of the TNT contamination area, as shown in Figure 19, to determine the extent of explosives contamination caused by the TNT washout and laundry operations. Only a limited number of analyses need be obtained for these wells.

4. Soil sampling of TNT area.

   A maximum of ten 5-foot cores should be taken within the explosives-contaminated area, including the TNT Washout Ponds. Each 6-inch interval of a core should be analyzed, as a separate sample, for the explosives found in this study.

5. South Area sediment sampling.

   A maximum of 10 surface soil and sediment samples should be obtained from the south-central portion of the South Area and analyzed for arsenic. The majority of these samples should be obtained from the Demilitarization Area/Demolition Pits. This will supply additional information for determining the origin or arsenic in this area. Additional reconnaissance should be undertaken to determine the possibility of arsenic contamination originating from off-site sources. Additional sediment samples may be collected and analyzed for arsenic. The sampling program should be designed to ascertain the existence of naturally occurring high arsenic levels.

6. Ground-water withdrawal assessment of Headquarters Area.

   A ground-water withdrawal assessment of the Headquarters Area would be extremely useful in determining the impact of pumpage of existing Wells 1 and 2 on the movement of the contaminant plumes from the Industrial Waste Pond, Outfall ditches, and Sewage Lagoon.

1.2.3 Third Priority Recommendations

Ertec suggests the following recommendations to obtain additional information on potential contaminant migration and hydrogeological conditions.

1. Complete Well N-7.

   This well can provide information to determine if any contaminants are migrating onto the site. It may be required by RCRA as an up-gradient sampling point for measuring background ground-water conditions. A surface soil sample should also be collected and analyzed at this point to determine if contamination is carried onto the Depot by surface run-off from the chemical and smelter activities in Bauer.

2. Install Well N-9.

   This well provides information at the boundary in the area immediately up-gradient of the nearest off-base well. It may intercept contamination plumes from sources such as the TNT and Laundry Pond area.

3. Re-drill Well N-6.

   Information on the Chemical Range can be obtained by re-drilling Well N-6 or completing a new well in a slightly different location.

4. Bedrock coring.

   At least three 20 to 40 foot cores of the bedrock in the vicinity of the Industrial Waste Pond should be obtained for chemical and physical analysis to determine potential for long-term contamination of the bedrock.

2.0 INTRODUCTION

2.1 Objectives

Ertec Western, Inc., was retained in September, 1981, by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA), Aberdeen Proving Ground, Maryland, and the Tooele Army Depot (TEAD), to conduct the Exploratory Stage of a contamination survey at the Tooele Army Depot, Tooele, Utah. The objective of this study was to determine whether toxic or hazardous materials are present in the surface and subsurface environments and whether they are migrating or have the potential to migrate off Tooele Army Depot property. The results of the study have been used to 1) detect possible contaminants crossing the boundary, 2) determine if any contaminated areas within the installation are presenting an imminent hazard to the off-post environment or to personnel working at the Depot, 3) determine background level of possible contaminants, 4) define general stratigraphical and lithological relationships, and 5) characterize the general hydrogeologic system, including definition of flow paths through ground-water and surface-water systems along which contaminants could migrate.

The survey was divided into two phases. The objective of Phase I was to assess the potential hazard that would result if contaminants were to migrate from source sites. This effort produced a Potential Contamination Matrix and Hazard Ranking Scheme for each source and contaminant, which in turn enabled Ertec to choose locations for sediment, soil, surface-water and ground-water sampling. The objectives of Phase II were to evaluate the Phase I assessment and provide additional information where necessary to fully ascertain potential migration of toxic and hazardous materials across Tooele Army Depot boundaries.

2.2 Acknowledgements

The authors wish to express their appreciation to Mr. Donald Campbell, Mr. John Sanda, and Dr. Les Eng of USATHAMA for assistance with the organizational and technical portions of the survey; and to Mr. Jerry Parkin of USATHAMA for his aid in communications and interaction between Depot personnel and consultants.

The authors also acknowledge the cooperation and assistance provided throughout the project by Ms. Rafaelita Martinez, Mr. Larry Fisher and Mr. Dave Jackson of the Tooele Army Depot, whose knowledge of the Depot greatly aided our study.

2.3 Sources of Information

Ertec Western, Inc., reviewed and assessed over 100 reports, documents and maps pertaining to Depot related activities and regional and local geology and hydrogeology. Selected abstracts are included as part of the Environmental Assessment in Appendix A. Environmental data were collected from USATHAMA, TEAD, U.S. Army Environmental Hygiene Agency (USAEHA), U.S. Geological Survey (USGS), the Soil Conservation Service, and the State of Utah's environmental and technical agencies. Much of the contamination data comes from TEAD's files relating to facility and site investigations for construction, water supply, and potential contamination.

2.4 Philosophy on Modifications and Reevaluation of Program Effort

Ertec's philosophy in conducting the environmental contamination survey at TEAD was to allow as much flexibility as possible while remaining within the scope of work set forth in the Technical Plan. This approach used data as they became available to reevaluate the adequacy of planned locations, depths, and sampling frequencies of the remaining wells and test holes. This approach was used at TEAD because of the paucity of data on the subsurface hydrogeologic regime prior to the study.

Additional considerations that were used to alter the sequence of data collection set forth in the Technical Plan included inclement weather, drilling conditions, and budget constraints. The sections that follow detail the changes from the Technical Plan. The program that was completed allowed for the most thorough technical effort within the constraints imposed by the above factors.

This report presents the results of the initial Phase I Environmental Assessment and the results of the field programs under Phase II. The Phase II program includes a methodology section, results section, and lessons learned from the program for future benefit.

The nine appendices included in three separate volumes present additional information on technical aspects of the project and present the data collected during the various programs.

3.0 RESULTS OF PHASE I ENVIRONMENTAL ASSESSMENT

3.1 Introduction

Phase I of the Environmental Contamination Survey was performed in October and November 1981. This section represents the final revision of the Environmental Assessment which was first presented to USATHAMA in November 1981, with Revision 1 presented in February 1982. The Phase I survey comprises a review of the existing environmental data. It includes a summary of Ertec's interpretation of the hydrogeological environment, a potential contamination matrix, and the results of a ranking system which have aided in depicting the sites having the highest potential of being contaminated by past or present activities of the Depot. The survey also includes discussion of the biological setting, general air quality considerations, and potential manmade pathways for contaminant movement. The results of the Phase I study have led to the development of the Phase II Technical Plan.

3.1.1 Program Objectives

The objective of the Environmental Assessment was to evaluate the relative degree of hazard involved with migration of contaminants from source sites. Potential sources of contamination occur in many sections of the North and South Areas of the Tooele Army Depot. The sources of the potential contaminants include ammunition, bulk explosives, industrial chemicals, including organics and inorganics, chemical agents, and low-level radioactive materials. In addition, the hydrogeologic system is complicated. Near-surface and subsurface formations vary from low to high permeability; the aquifer systems vary from deep zones with water levels at 300 feet to shallow zones with water levels at about 20 feet. However, very little site-specific information was available about the ground-water flow system or contamination migration patterns. Furthermore, the potential for these contaminants to migrate past the Depot's boundaries either through the ground- or surface-water systems, the air, or biological species, was unknown.

A Potential Contamination Matrix and Hazard Ranking Scheme for each source and contaminant was produced. These are detailed on hazard ranking sheets included in Appendix A.

3.1.2 Phase I Summary

During this initial phase of work, Ertec has collected and evaluated relevant regional-, site-, and area-specific information relating to the environment, sources of contamination, and the nature, characteristics, and extent of the aquifer system underlying the site. Environmental data have been collected from TEAD, USATHAMA, USAEHA, U.S. Geological Survey, the Soil Conservation Service, and the State of Utah's environmental and technical agencies. TEAD's files relating to facility and site investigations for construction, water supply, and potential contamination also have been evaluated.

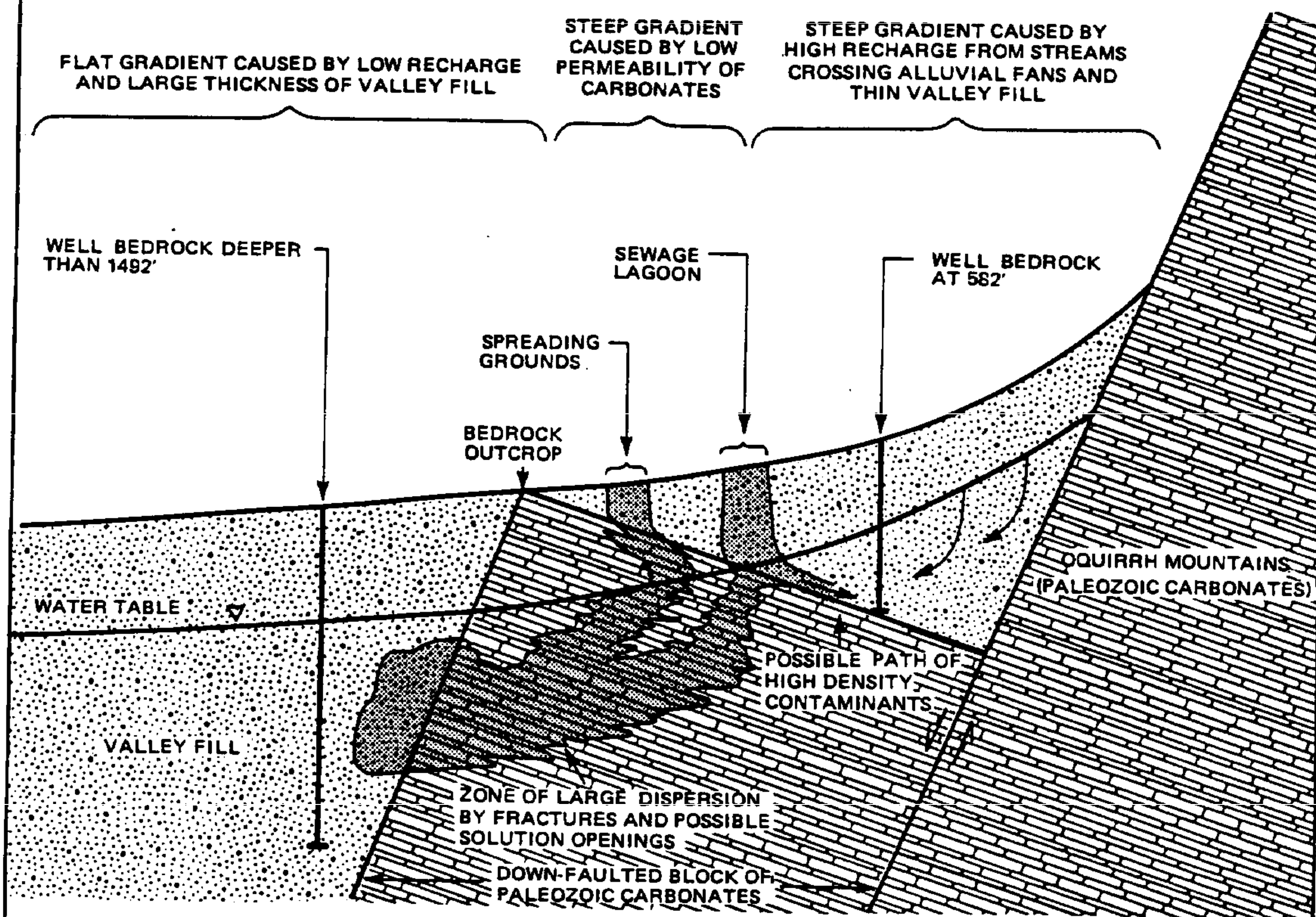
The data review focused on regional and site-specific information in order to gain an understanding of the environmental setting at TEAD and to estimate the potential for contaminants to migrate past the boundaries of the installation. Using these data, Ertec interpreted the geological environment, the geometry of the flow system, flow directions, relative flow rates, relative aquifer characteristics, recharge and discharge areas, quantity and quality of water withdrawn from existing wells, and soil types. In addition, potential for contamination migration in the surface-water, biological, and atmospheric systems has been reviewed. The potential for contaminants to migrate along man-made pathways also has been examined. The results of the Phase I Environmental Assessment are included without revision based upon data collected during Phase II. The revised versions of several items such as potentiometric surface maps are included in the section summarizing Phase II. Inclusion of both sets of information permits an evaluation of hypotheses formulated during Phase I.

3.2 Summary of Environmental Assessment

The data evaluated to conceptualize the geological and hydrogeological system comprised published and unpublished reports provided by the records search conducted by USATHAMA, visits to TEAD and State and Federal agencies by Ertec personnel, and field reconnaissance by vehicle and helicopter during the week of October 12, 1981. The following discussion summarizes the conceptual geologic and hydrogeologic systems for the North and South Areas of TEAD based upon this evaluation. The summary is oriented towards the movement of contaminants towards the boundaries of TEAD. This summary is abstracted from Appendix A-1, Environmental Assessment.

3.2.1 Geological and Hydrogeological Summary of the Tooele Army Depot North Area

The North Area of the Tooele Army Depot lies in Tooele Valley, Utah, approximately 35 miles southwest of Salt Lake City. Tooele Valley is a typical valley of the Basin and Range Province in that it most likely consists of a complex collection of troughs and ridges that have been partially or completely buried by more recent sediments. Through the study of a number of faults running through the valley and several bedrock outcrops occurring in the north east and south central portions of the Depot, Ertec hypothesized the existence of a buried bedrock ridge running diagonally across the Depot between the bedrock outcrops. This hypothesized bedrock ridge and its hydrologic significance is illustrated in Figure 1. Ground-water flow through the Depot



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HYPOTHETICAL CROSS–SECTION A–A′
THROUGH NORTH AREA

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FIGURE 1

is from the east and south towards the center of the valley and ultimately north to the Great Salt Lake. The movement of contaminants from sources in the area of the buried ridge can be significantly affected by this feature, as shown in Figure 1.

The depth to static water level at the TEAD North Area ranges from less than 200 feet in the north central area to over 600 feet in the south west area. The transmissivity and storage coefficient have been estimated to be 60,000 ft^2/day and 0.002, respectively.

The saturated thickness of the valley fill sediments is 1500 feet or more. Ground water occurs in these sediments under unconfined and semi-confined conditions. The bedrock underneath the valley fill is comprised of carbonate sediments of Paleozoic age. These rocks are the same ones that outcrop on the Depot and that comprise mountains on the east, south, and west of TEAD. Additional information on the topography, geology, hydrology, climate, biota, and air quality, are found in Appendix A-1.

3.2.2 Geological and Hydrogeological Summary of the Tooele Army Depot South Area

The South Area of the Tooele Army Depot lies in Rush Valley, Utah, approximately 17 miles south of the North Area. Rush Valley, a topographically closed valley, is separated from Tooele Valley by a geologic feature known as a baymouth bar formed by Pleistocene Lake Bonneville. The surficial and subsurface geology of the South Area is very similar to that of the North Area, exhibiting typical Basin and Range structure. Shallow ground water generally occurs under unconfined conditions. Confined conditions may exist in deeper valley fill sediments.

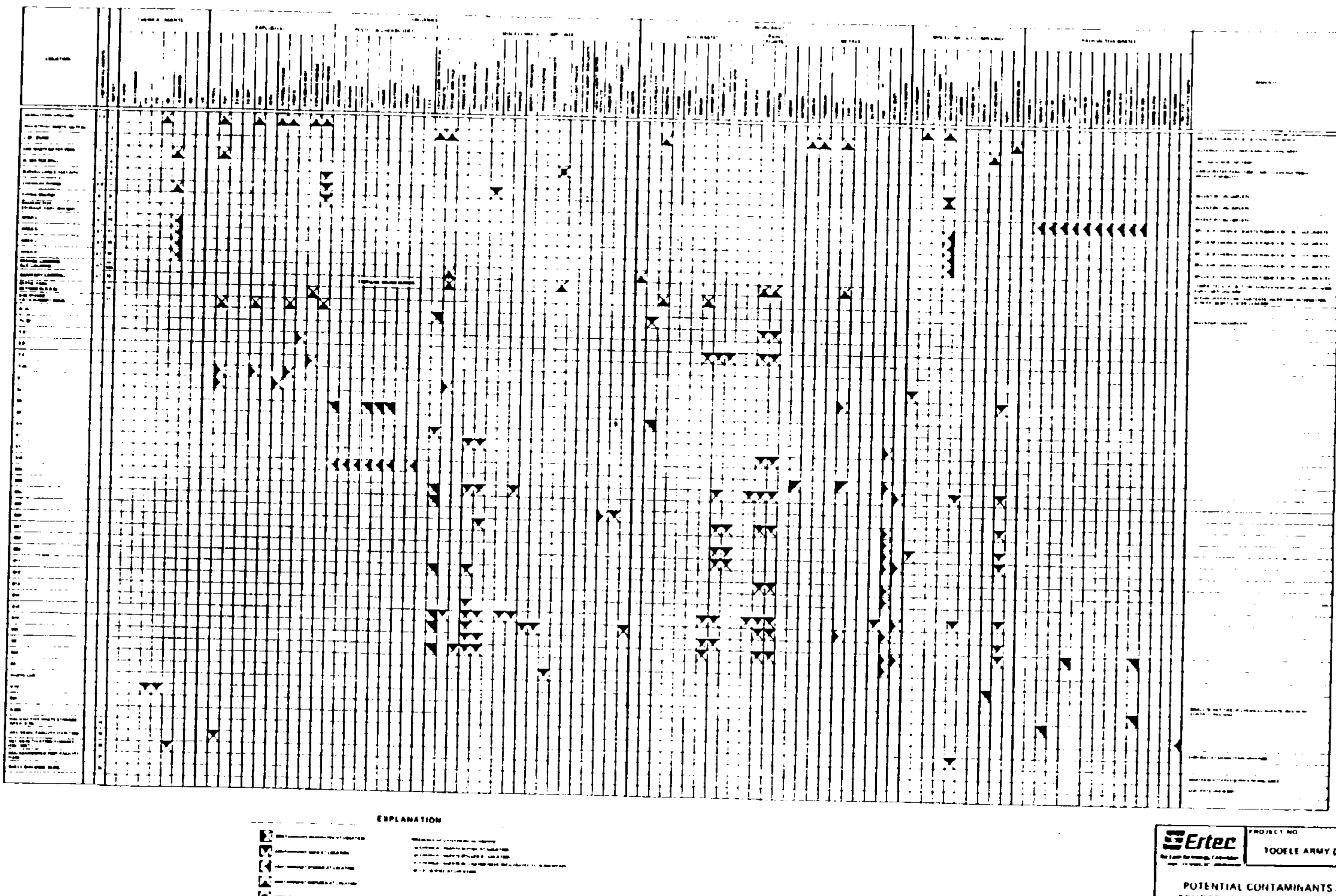
Ground water moves towards two separate discharge areas. Ground water originates as recharge along the eastern and western valley edges, and flows predominantly to the southwest and west towards the center of the valley. Ground water discharges by evapotranspiration in the playa that exists as part of the south and southwest portion of the South Area. The depth to water in this area is shallow and the discharge by evapotranspiration provides a concentrating mechanism for dissolved constituents.

The depth to static water level at the TEAD South Area ranges from over 300 feet in the northeast to less than 15 feet in the southwest. Because of the presence of fine-grained lacustrine deposits, the water table aquifer has a very low transmissivity. Water supply wells in the area tap deeper, more productive aquifers. The extent of connection between the water table aquifer and these deeper aquifers is not known. Approximately 5000 acre-feet per year of ground-water flows from Rush Valley to Tooele Vally under the bay-mouth bar separating the two valleys.

3.3 Potential Contamination Profile

3.3.1 Objectives

A potential contamination profile was developed through a two-fold process. Contamination matrices were constructed for both the North and South Areas of the Tooele Army Depot, Figures 2 and 3. These matrices were designed to identify possible site-specific sources of contamination to the hydrosphere. These matrices consider sources, contaminants, environmental criteria, detection levels, and the manner in which the potential contaminants are present at a location. The matrices are then used in conjunction with a Hazard Ranking System, in which each source is evaluated and ranked based upon source type,



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TOOELE ARMY DEPOT

POTENTIAL CONTAMINANTS AND SOURCE LOCATIONS NORTH AREA

Figure 2

route characteristics, containment, waste characteristics, targets, and waste quantities. The hazard ranking sheets for each source area are found in Appendix A.

Where potential contaminants were not identified, either from the record search conducted by TEAD and USATHAMA personnel, or in the review of the available documentation carried out during the development of the matrices, the locations were omitted from the matrices. As a consequence, the contents of the matrices were subject to review as the investigation program continued. Consideration also was limited to site-specific sources, so that possible contamination from such sources as the depot-wide use of pesticides and other hazardous chemicals were not considered in the matrix. A review of the available documentation indicates that such dispersed sources should not be a significant cause of contamination. Finally, the matrices were designed to address problems of contamination in the hydrosphere. Biological pathways are discussed in Appendix A-1, and it was concluded that contamination via ground or surface water was of greater concern than introduction of contaminants through the food chain. Sources of air pollution were not explicitly considered, as such problems have been investigated in a number of studies at TEAD, and these results were discussed in Appendix A-1.

3.3.2 Matrix Form

The matrices were designed to examine all of the significant contaminants identified in a review of the documentation from TEAD. The potential contaminants were categorized as chemical agents, organic compounds (including pesticides, herbicides and miscellaneous compounds), inorganic compounds (acids, metals and miscellaneous compounds), and radioactive elements.

The source locations were identified by a brief description or building number, and are keyed to source maps of the North and South Areas by numbers (see Plates II and IV in Appendix A-1). In the North Area, due to the large number of potential contamination locations, only those assessed to be significant during the development of the matrix and the hazard ranking process are keyed to the source map. The presence of buried unexploded ordnance (UXO) and spilled or buried chemical agents also is recorded on the matrices.

The matrix notation was developed to illustrate symbolically the manner in which potential contaminants are present at a site. A five-fold system has been used in which a contaminant is described as being either: 1) generated, that is, manufactured or produced as a byproduct, 2) used, 3) stored, 4) disposed or 5) spilled. A potential contaminant which has been buried, burned or discharged into an evaporation/infiltration pond is described as having been disposed at a site. A brief note on the method of disposal at a location is contained in the "comment" column of the matrices.

3.3.3 Matrix Documentation

The matrices were based primarily on the results of the Record Search at TEAD (USATHAMA Report No. 141), and its supporting documentation. This information has been supplemented by an examination of the TEAD literature which postdates the Record Search, by a field reconnaissance by Ertec personnel and the integration of a preliminary contaminant matrix developed by Mr. Donald Campbell of USATHAMA. For each potential source location identified, a detailed search was made of the original documents to determine as fully as possible the type and manner of occurrence of contaminants.

The location of these sites was obtained from maps of the North and South Areas provided by TEAD, as well as from the annotated maps which resulted from interviews with present and former TEAD personnel. The results of the investigation are summarized on the source maps of the TEAD areas (Plates II and V) and the matrix itself, Figures 2 and 3.

3.4 Ranking of Potential Contamination Sources

To facilitate the determination of well and surface-water sampling locations, and to narrow the list of potential sites, Ertec prioritized the contaminant sources listed in the Potential Contamination Matrix. Modification of the Hazard Ranking System, designed and tested by the EPA and MITRE Corporation (Caldwell et. al., 1981), was developed to provide a rational framework for validly ranking these sources. Each source is evaluated for six categories consisting of one or more factors. Each factor is assigned a numerical value acording to prescribed guidelines which are discussed in Appendix A-2. This value is then multiplied by a weighting factor or Multiplier to yield the total factor score. Factor scores within a category are added to give a total category score.

Category scores are multiplied together, resulting in a total score for a source. By dividing this score by the maximum achievable score, a normalized score is obtained which, when compared to all other sources, results in a relative ranking of the potential hazard represented by each source. Figure 4 shows an example ground-water contamination ranking sheet which evaluates the Industrial Waste Pond area. Included in Appendix A are worksheets for each of the identified contaminant sources.

SITE ID: North 2 Industrial Waste Outfall Area

GROUND-WATER ROUTE WORK SHEET

RATING CATEGORY	ASSIGNED VALUE	MULTIPLIER	SCORE	MAX. SCORE
1 SOURCE TYPE (CHOOSE ONLY ONE FACTOR)				
DISPOSED	5 10	1	10	
GENERATED OR USED	2 5	1		
STORED	1	1		
TOTAL SOURCE TYPE SCORE			10	10
2 ROUTE CHARACTERISTICS				
UNSATURATED ZONE TRAVEL INDEX	0 8	2	16	16
SATURATED ZONE FLOW PATH DISTANCE TO WELL BOUNDARY	0 1 2 3 6	2	6	12
TOTAL ROUTE CHARACTERISTICS SCORE			22	28
3 CONTAINMENT	0 1 2 3	1	3	3
4 WASTE CHARACTERISTICS				
PHYSICAL STATE	1 2 3	1	3	3
PERSISTENCE IN SUBSURFACE	0 1 2 3	2	6	6
TOXICITY	0 1 2 3	2	6	6
TOTAL WASTE CHARACTERISTICS SCORE			15	15
5 TARGETS				
WATER USE	1 2 3	3	9	9
POPULATION SERVED	1 2 3 4 5	6	30	30
TOTAL TARGETS SCORE			39	39
6 WASTE QUANTITY	1 2 3 4	1	4	4
7 TOTAL SCORE			1,544,400	1,965,600
NORMALIZED SCORE (PERCENT)			78.6	

EXAMPLE GROUND-WATER CONTAMINATION RANKING SHEET

FIGURE 4

The results of the ranking system are shown in Table 1. This table presents the potentially contaminated sites in order of the relative potential hazard they represent.

An action level was chosen at a score of about two percent. As shown in Figure 5, the relative frequency distribution of the results of the ranking system shows natural breaks between the one and two percentile level and the ten and 15 percentile level, suggesting that sites which received a value above the latter level represent a much more significant hazard than those below this level. Sites receiving values between two and 12 percent are considered to merit some investigation but are not as sensitive. Further analysis showed that over 50 percent of all ranking values are less than two percent. Sources having a score below two percent were not considered to have a high enough contamination potential to merit action at this time, based on the scope of work and the low possibility of these contaminants to migrate past the Depot boundaries. The low scores are principally due to the storage practices such as well-sealed containers, to the deep water table with very little probability of vertical migration, or to the great distances to the Depot boundary.

TABLE 1 - Results of Ranking Procedures to Determine Potential for Ground Water Contamination, Tooele Army Depot.

Rank	Normalized Score (%)	Area(1)	Site(1)	Location
1	78.6	North	2	Industrial Waste Outfalls and Spreading Grounds Area
2	64.3	North	17	TNT Washout Ponds and Outfall
3	44.4	North	15	Sanitary landfill
4	33.3	North	14A	Old Sewage Lagoon
5	24.0	South	13	CAMDS
6	23.6	North	16	Septic tank 56 from Building S-33
7	18.0	South	6,7	Pond & Leach Pit, Bldg. T-600
8	11.1	North	14	Sewage Lagoon
9	9.9	South	2	Gravel Pit (Area 10)
10	8.8	South	1	Demilitarization Area
11	7.1	North	3	Pond, Bldg. L-23
12	6.4	North	4	Waste Water Pond, Bldg. 1303
13	5.4	South	28	Craters, Southwest Area
14	4.1	South	25	Windrows
15	4.0	South	22	Holding Ponds, Bldg. 554
16	3.3	South	23	Holding Area, Demilitarization Leakers
17	3.3	South	4	Pit (Area 2)
18	2.4	North	7	Chemical Range
19	2.2	South	26	Sanitary Landfill

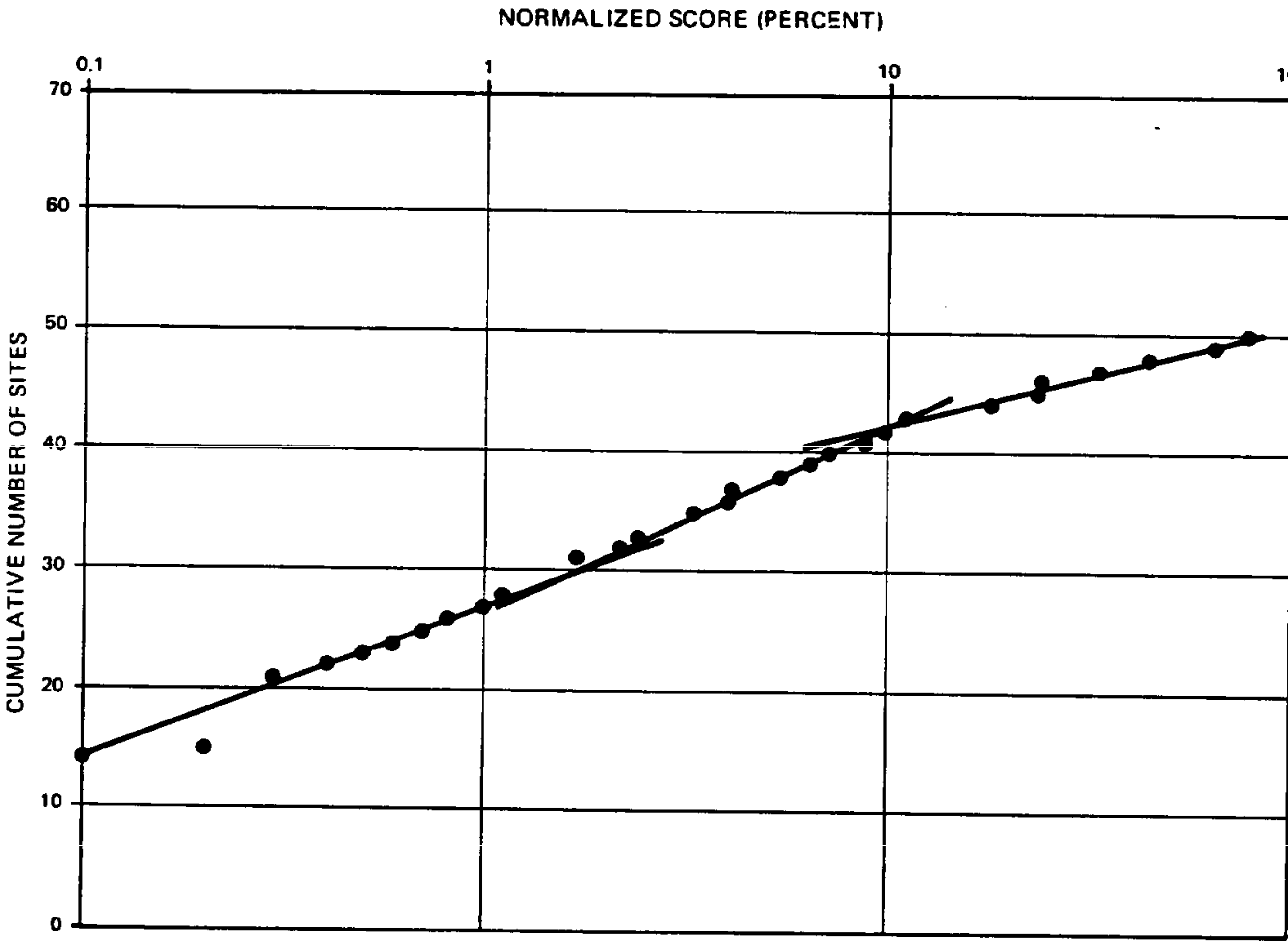
Below this line, normalized scores are less than 2% and therefore considered as insignificant problems and are not ranked.

--	1.7	North	20	AEO Deactivation Furnace (1351-1357)
--	1.6	North	1	Demolition Grounds
--	1.6	South	9	Holding Area (near Area 2)
--	1.1	North	5	PCB Spill, K281
--	1.0	South	8	T3250/3251 and Associated Pits
--	0.8	South	3	Leakers in Area 2
--	0.7	South	24	Old Demilitarization Shack and S-3200
--	0.6	North	22	Shell Bldg.
--	0.5	South	15	C-4002
--	0.4	North	8	Firing Range
--	0.3	South	11	Area 10
--	0.3	North	6	Surveillance Test Site
--	0.3	South	20	S-541
--	0.3	South	21	Bldg. 553

Table 1 (Continued)

Rank	Normalized Score (%)	Area[1]	Site[1]	Location
--	0.3	North	19	AEO Demilitarization Facility (1370-1380)
--	0.3	North	21	AEO Abandoned Test Facility
--	0.2	South	10	Spill near Area 9
--	0.1	North	18	Radioactive Waste Storage Area S-753
--	0.07	North	9	Radioactive Storage Yard
--	0.05	South	27	Gravel Pit
--	0.02	South	16	S-119
--	0	South	5	Bldg. T-600
--	0	South	12	S-118
--	0	South	14	S-108
--	0	South	17	Bldg. 520
--	0	South	18	Bldg. 532
--	0	North	10	Area C
--	0	North	11	Area G
--	0	North	12	Area J
--	0	North	13	Area K
--	0	South	19	Bldg. 533

(1) Keyed to Plates II and V by area and site, Appendix A-1.



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TOOELE ARMY DEPOT

RELATIVE FREQUENCY DISTRIBUTION
OF HAZARD RANKING RESULTS

11-82

FIGURE 5

4.0 METHODOLOGY FOR PHASE II TECHNICAL EFFORT

During the Phase II study, soil, sediment, surface-and ground-water samples were collected. Specific protocols and techniques were developed to perform this work.

The methods developed and used in this assessment are discussed in detail in Appendix B of this report. Many of the methods were developed by USATHAMA and recognized as standard operating procedures, such as well drilling and construction and many of the laboratory chemical analyses. Others were developed for USATHAMA for this project, such as the modification for explosives analyses; and still others were developed for USATHAMA for previous projects, such as the water sampling protocol and techniques developed by Ertec for the Rocky Mountain Arsenal (Recommended Ground-Water Sampling Protocol and Monitoring Program for Rocky Mountain Arsenal, Denver, Colorado, 1982). All methodologies were designed to obtain the most accurate and reliable results possible, and are acceptable to other state and federal agencies, including the EPA.

The methods discussed in Appendix B include the following: Methodology for Well Installation; Methodology for the Collection of Soil, Sediment, and Surface-Water Samples; Methodology for the Collection of Ground-Water Samples; and Methodology for Chemical Analyses.

5.0 RESULTS OF PHASE II TECHNICAL EFFORT

The Phase II technical effort included geophysical studies, well drilling and construction, surface-water, ground-water, soil, and sediment sample collection, and chemical analyses. The results of these studies were integrated and evaluated to produce a coherent picture of the potential for contaminant migration at the Tooele Army Depot. Considerable emphasis was placed on characterizing the ground-water system, defining the mechanisms of contaminant migration, and determining the potential effects of contaminant sources on the ground water.

5.1 Program Modification

The exploratory program, as described in the technical plan, was modified several times during the course of this investigation. The reasons for the changes included logistic, technical, and fiscal considerations. The major changes to the proposed program are summarized below. All modifications were incorporated only after receiving oral and/or written approval from USATHAMA and/or TEAD representatives.

5.1.1 Drilling Program

The technical plan described the drilling of 11 wells in the North Area, and 17 wells or borings in the South Area. It was planned to drill and sample the sites generally in the order of importance based upon their hazard ranking as described in Section 3.0. The order of drilling was significantly altered by field conditions such as access, weather, and availability of drilling equipment and personnel. The wells with the highest ranking actually were drilled last in most cases.

Additional wells and borings were installed at sites N-8A, N-3B, N-2B, N-2C, and S-15. N-8A was installed solely at the request of USATHAMA to confirm the continued absence of a perched water table at the north boundary of the North Area. Well N-3B was installed after a perched zone was identified in Well N-3A. Boring N-2B and Well N-2C were installed to sample the perched zone under the Industrial Waste Pond after water balance computations determined that such a zone had a very high probability of existing, and after Well N-2A had been drilled to carbonate bedrock. Boring S-15 was added when reevaluation of the potential hazard of an abandoned landfill indicated a significant potential for contamination.

Wells N-1, N-5, N-8C, N-9, S-13, S-12B, S-12C, and S-5B were deleted from the drilling program; Well N-7 was not completed below a depth of 75 feet; Well N-1 was deleted; and Well N-4 was moved to sample ground water affected by both the Sewage Lagoon and the Spreading Grounds. These actions were taken to allow sufficient project funds to complete wells at sites having a high hazard ranking in the North Area. The installation of a well in the vicinity of site N-9 and the completion of Well N-7 have been recommended as a third priority item.

5.1.2 Sampling Program

No significant changes were implemented in the sampling program for soil, ground water, surface water or sediment.

5.1.3 Chemical Analysis Program

Modification of the methods used to preserve explosives and the HPLC methods used for explosives analysis were incorporated with the approval of Dr. Les Eng of USATHAMA. A modification of the method used to determine wetting volume for soil samples prepared by the solid waste leaching procedure (SWLP) was incorporated. These modifications are described in Section 6.2.

5.1.4 Data Management

All required geotechnical data from drilling and sampling, and all chemical data have been entered onto a 9-track tape to be submitted to USATHAMA for entry into Tier 1 files. The merging and editing of the many small files created during data collection was more efficiently done by entering these files into Ertec's Data Base Management System (DBMS) on our Harris 800 computer, than using the Univac 1100 system at USATHAMA. The Ertec DBMS files maintained the same format as the USATHAMA Tier 1 files. This system was also used for the chemical data. This method allowed rapid entry of semi-quantitative analytical values that resulted from applying the slopes of semi-quantitative certificating curves to the qualitative values. The savings to the project from not having to enter the entire records via the data entry programs was about $7,000.

Another minor modification resulted from using Ertec's in-house software for plotting and contouring water level data rather than Level 4 programs in USATHAMA's system.

5.2 Geophysics Program

The geophysics program originally included only the magnetic surveys, which were a tool to map potential drilling sites for unexploded ordnance (UXO's) and buried drums. The program was expanded considerably because of the results of the Phase I study. During this study and subsequent field inspections, the importance of the bedrock outcrops discovered in the North Area became evident. It became apparent that a bedrock ridge extending across the site would have a significant impact on the movement of ground water and contaminants from such sources as the Industrial Waste Pond, the Sewage Lagoon, and the TNT Washout Area. A preliminary study using the gravity technique was designed and conducted as the most cost-effective procedure for obtaining verification of the hypothesized ridge. Results indicated a ridge was indeed present and very likely would affect ground-water movement, particularly in the vicinity of the Industrial Waste Pond. Consequently, seismic refraction and electrical resistivity studies were designed to "fine tune" the gravity survey, determine the subsurface structure of the bedrock ridge, and provide additional hydrogeological information for this area. Prior to conducting the actual field seismic refraction program, a blast test was required by the Depot Safety Division and by the Ammunition Surveillance Division because of concern about ammunition stored in some of the igloos. Results of the blast test showed there to be insignificant effect on the stored ammunition if slight modifications were made in the design of the seismic study. The results of the blast test were included in a separate report previously issued to USATHAMA and the Tooele Army Depot. The results of the geophysical program are discussed in the following sections. Techniques and details of the program are included in Appendix D.

5.2.1 Results of Magnetic Survey for Clearing Drilling Sites

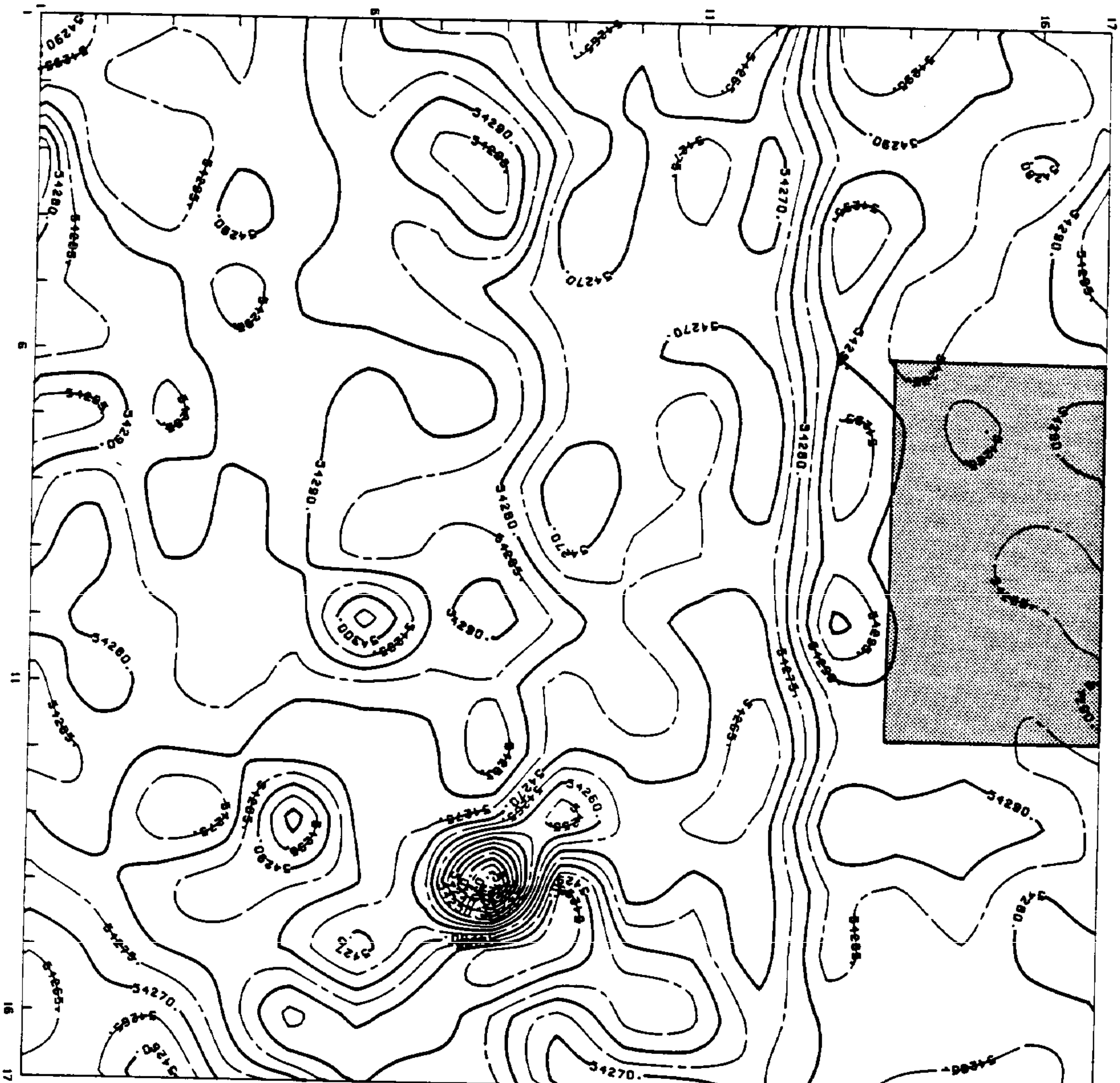
Ground magnetic surveys were performed at three potential drilling sites in the North Area of TEAD and four sites in the South Area for the purpose of detecting buried metallic objects, which might have posed a hazard to personnel involved in drilling. The surveys were designed to detect unexploded ordnance or objects equivalent to a 55-gallon steel drum buried as deeply as 15 feet.

The magnetic contour maps that were produced from the surveys were analyzed to select safe drilling sites by avoiding areas of high magnetic relief. An example of one such analysis is shown in Figure 6. The shaded area in the figure is considered safe for drilling. Actual drilling at this site was done as close to the center of the shaded area as terrain would allow. A detailed explanation of the magnetic survey program is included in Appendix D, along with the magnetic anomaly maps for sites N-4, N-6, N-6NEW, S-6, S-9,and S-15. Drillable areas were found in all sites with the exception of N-6NEW, which was subsequently moved to a more suitable area.

5.2.2 Results of Gravity Survey

A gravity survey was conducted at the Tooele Army Depot. The purpose of the survey was to obtain gravity data to provide a conceptual model of the contact between unconsolidated basin fill materials and the underlying bedrock. This model, together with the results of hydrologic studies, has provided information to understand the ground-water flow regime and pathways that transport and distribute potential pollutants. The preliminary gravity results were used to select locations for seismic refraction survey lines and electrical resistivity soundings. Data from the refraction lines corroborated the gravity interpretation.

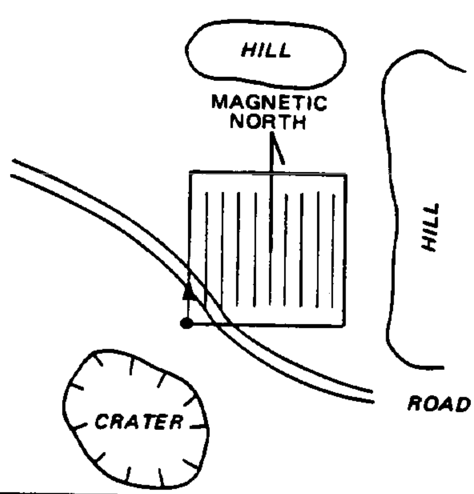
A contour map of terrain-corrected Bouguer (gravitational) Anomaly (shown and discussed in Appendix D-2) was produced to estimate the depth to bedrock using a linear inverse modeling method. The Bouguer Anomaly values were first corrected to remove the east-west regional gravity gradient caused by the crustal and mantle structure transition. The estimated depth to bedrock is shown in Figure 7. The contour values are in feet.



AREA CONSIDERED SAFE FOR DRILLING

10 FEET

CONTOUR INTERVAL: 5 GAMMA



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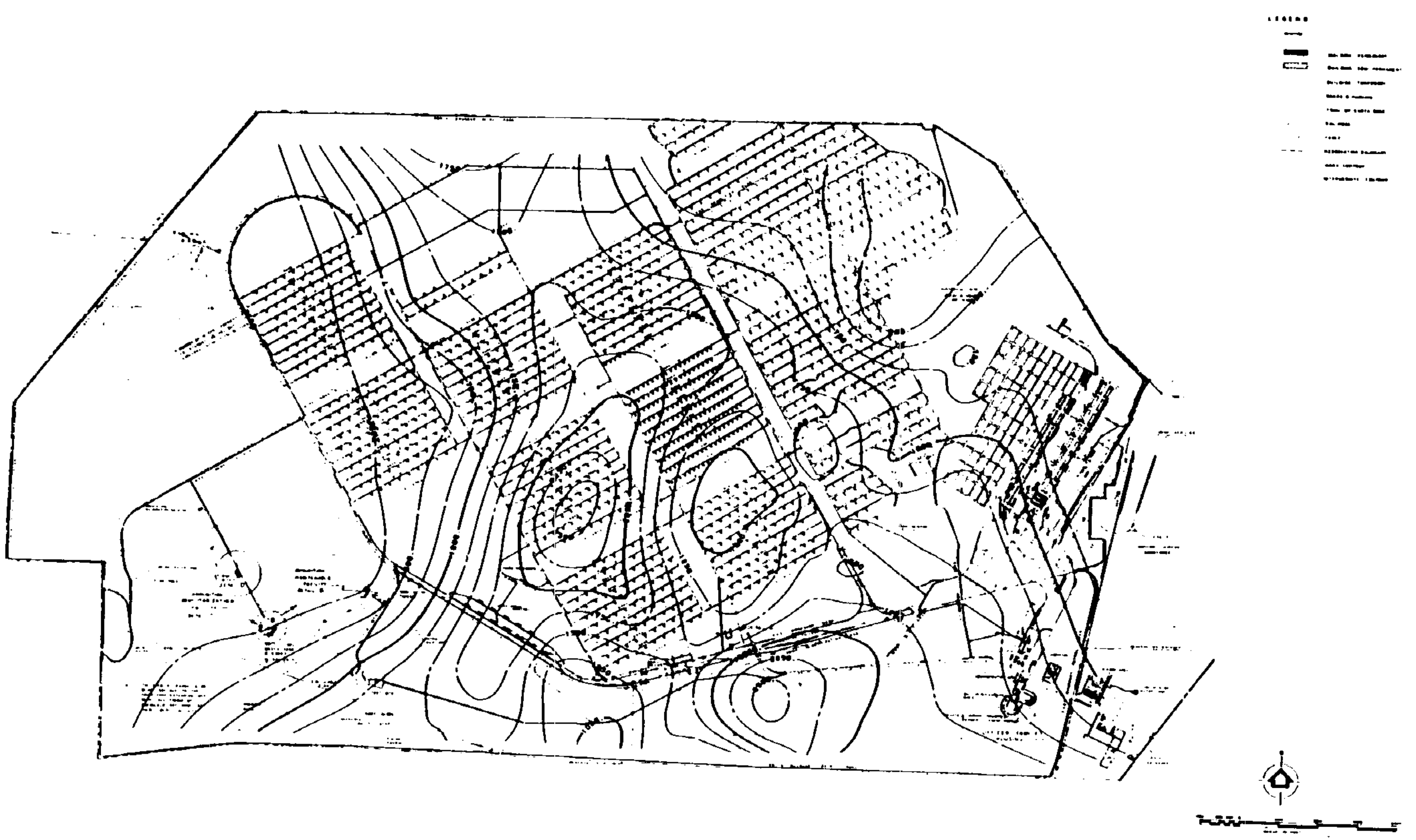
USATHAMA
DRILL SITE SURVEYS

MAGNETIC ANOMALY MAP
SITE S-7

2-82

FIGURE 6



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PROJECT NO 82-160

TOOLE ARMY DEPOT
USATHAMA

DEPTH TO BEDROCK
AS INTERPRETED FROM
GRAVITY DATA

FIGURE 7

Caution should be used when interpreting the modeled depth-to-bedrock surface. The inverse modeling method used is capable of handling only a single density contrast (a single interface) at a time. This limitation would not be a concern if a very uniform alluvium overlying a uniform bedrock were present. However, logs of test wells and water supply wells show that neither the alluvium nor the bedrock is uniform. The alluvium may vary from relatively dense and well compacted Tertiary-aged material to unconsolidated low-density Quaternary material. Bedrock may vary from high-density carbonate rocks to relatively lower density sandstones and quartzites. Further complicating the situation is the presence of various volcanic rocks which may vary in density from that of the alluvium to nearly that of the bedrock. Finally, the density of the alluvium may increase with depth because of compaction caused by overburden loading. A density contrast of 0.4 gm/cm^3 west of the trend of gravity highs and a density contrast of 0.6 gm/cm^3 east of this trend were used, with interpolation between these two values in areas near the gravity highs.

Despite these complicating factors, the depth-to-bedrock contour map provides a reasonably good representation of the depth to well-consolidated rock, whether its composition is volcanic, carbonate, or quartzitic. The only known major error in the interpreted bedrock configuration is in the extreme western part of the study area where the computed depth to bedrock is too shallow. Well data from this area indicate a depth to bedrock that is deeper than 500 feet. The existence of intermediate density alluvium and volcanic rocks in this area and perhaps some remaining regional gradient may have caused the modeled depth to bedrock to be too shallow. In all other areas of the map, the calculated depths are probably correct to within $\pm$ 10 percent, based on comparison with known depths from well logs. Additionally, the depths to bedrock are consistent with the results of the blast monitor test and the refraction lines.

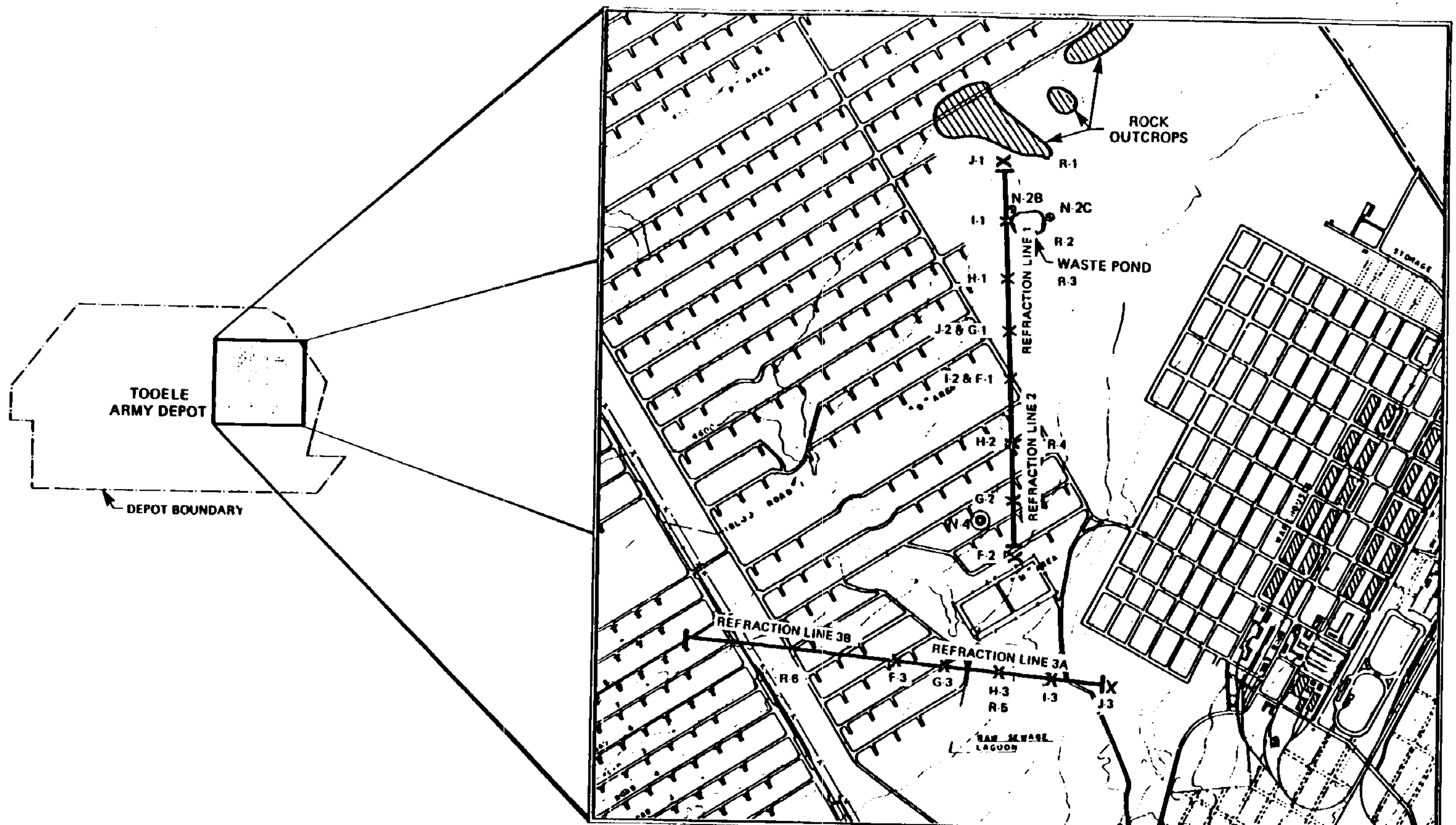
5.2.3 Results of Refraction and Resistivity Surveys

Three geophysical techniques, gravity, seismic refraction, and electrical resistivity, were used to delineate the subsurface structural features which may affect ground-water movement. A generalized basement-rock model of the valley was derived from the gravity survey previously discussed. There were three objectives of the seismic refraction/electrical resistivity survey:

1. To determine subsurface structure south of the northern rock outcrop.
2. To determine if these methods can be used in this area of TEAD, to provide information on hydrologic conditions such as perched water tables.
3. To provide a constraint for the interpretation of the gravity survey.

The seismic refraction survey was completed in the vicinity of the northern rock outcrop on the east side of the Depot as shown in Figure 8. The results of the location of this survey were used to calibrate the gravity basement model and to confirm the existence and provide additional detail of the shallow bedrock ridge that extends south from the outcrop.

The refraction technique can delineate subsurface structure where an appropriate seismic velocity contrast exists between two adjacent strata. The technique measures the time required for a seismic wave to travel from a point of generation through the ground to detectors located on the surface. Wave arrival times are used to calculate the seismic velocities in the various strata. Geologic stratigraphy and structure can be inferred by analyzing these velocity data.



NOTE: BASE MAP IS THE TOOELE ARMY DEPOT GENERAL SITE MAP (MAY 1981)

0 1600 3200 FEET

SCALE 1:19,200

EXPLANATION

R-1 ELECTRICAL RESISTIVITY SOUNDINGS

G-3 SHOT POINTS

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TOOELE ARMY DEPOT

LOCATION OF RESISTIVITY AND REFRACTION ACTIVITIES

Electrical resistivity soundings were conducted at various locations along the refraction lines. This technique can delineate strata which have a resistivity contrast with the surrounding material. The method has been frequently useful in mapping aquifers because concentration and mobility of charged particles are the primary factors determining a material's resistivity.

Significant ground-water in alluvium can usually be observed by both the seismic refraction and electrical resistivity techniques. The seismic compressional wave velocity in fine-grained materials such as sand or clay is generally less than about 3000 feet/second (fps) when it is dry, but the velocity is between 4800 and 5500 fps when it is saturated. Saturated zones interpreted from seismic results should be correlated with other data because several dry earth materials also have characteristic velocities within this range.

Ground-water is usually slightly saline and normally appears as a low resistivity zone in the sounding results. A subsurface zone with a seismic velocity between 4800 and 5500 fps and a low resistivity value could be logically interpreted as being a saturated zone.

The results of the refraction and resistivity surveys have indicated the following:

1. Nature of Outcrop

   The northern rock outcrop is the surface expression of a much larger rock mass. The measured seismic velocity of the rock is 12,000 fps, which is within the range of velocities typically measured in carbonate rock.

2. Bedrock Surface

The rock surface dips towards the south in a series of terraces. The three terraces are probably separated by two fault zones. The average depths of the terraces beneath the seismic line are:

- o 180 feet (northern terrace)
- o 400 feet (central terrace)
- o 950 feet (southern terrace)

The carbonate rock is not detected by the east-west refraction line which is 1800 feet south of the north-south line. The depth of penetration with the seismic survey under this line was calculated to be 1270 feet.

3. Overburden Layering

There are three distinct subsurface velocity layers overlying the bedrock. These are interpreted to be:

Colluvium -	mostly unconsolidated sands, silts and gravel.
Non-indurated fanglomerate -	a variable-cobble matrix filled with unconsolidated, fine-grained material.
Cemented conglomerate -	a variable-cobble matrix filled with cemented fine-grained material.

The inhomogeneity in the colluvium is expressed in the wide range of observed velocities, 1100 to 2200 fps. The zone of non-indurated fanglomerate has a velocity ranging from about 5100 fps on the N-S line to 2900 fps on the E-W line. The cemented conglomerate also has a higher velocity (9100 to 9400 fps) beneath the N-S line than it does beneath the E-W line (7700 fps). The differences in the velocity layering between the two lines may be caused by anisotropy, differences in the materials, differences in the moisture content, or a combination of these factors.

4. Geologic Structures

Several structural features are interpreted from the refraction survey. Two bedrock fault zones are interpreted beneath the north-south refraction lines. They are located approximately 2000 and 6000 feet south of the outcrop. The approximate vertical offsets on the faults are:

150 feet (northern fault zone)
550 feet (southern fault zone)

The east-west line was positioned to cross a large gravity gradient which might indicate a fault. The seismic data indicates a vertical offset in the 7700 fps layer near the center of line 3B, which is also near the gravity gradient. The offset in this layer is on the order of 40 feet but it could be caused by a larger displacement in the bedrock. Bedrock structure at this location is too deep to be determined by the refraction line geometry.

Another structure is indicated by the velocity anomaly in the fanglomerate material at the center of the north-south line. The velocity of the anomaly is 6800 fps which is about 33 percent higher than the velocity of the surrounding material. The cause of the anomaly is interpreted to be a buried stream channel. The base of the channel is about 700 feet wide and about 300 feet below the surface. The higher velocity may indicate that material in the channel is much coarser than the surrounding material.

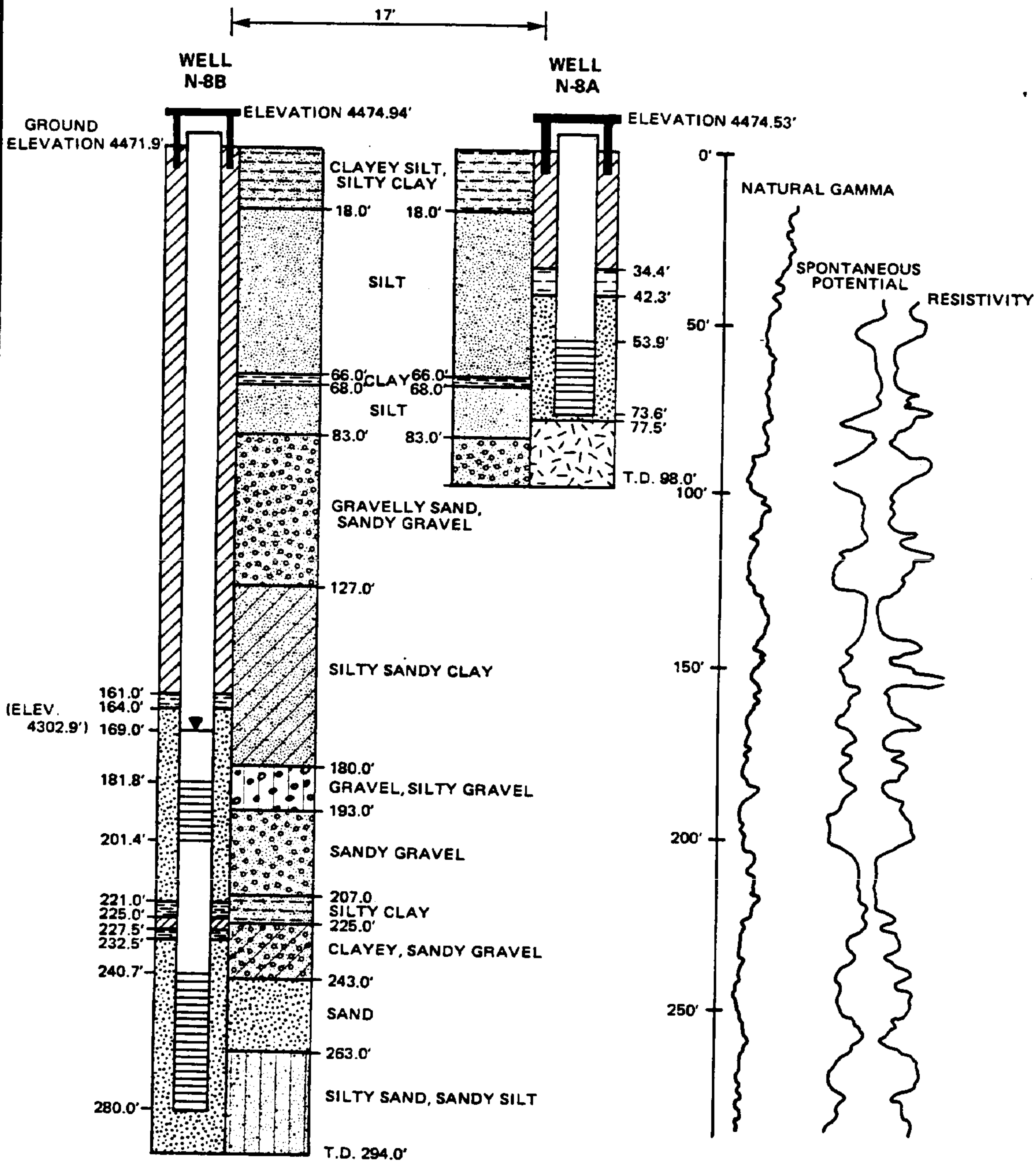
5. Water Saturated Zones

The results of the two surveys indicate that there may be a perched water zone beneath the north-south line, but not under the east-west line. The perched water zone may exist at the north-south line because of well-developed cementation of the underlying conglomerate. The fact that the velocity in this zone is higher than it is beneath the east-west line indicates better cementation beneath the north-south line.

For a more detailed discussion of the Geophysics Program, see Appendix D.

5.3 Hydrogeological Interpretation

Ertec has incorporated data collected from the field program with the existing data previously utilized in the Phase I study to provide an interpretation of hydrogeological conditions occurring in and around the North and South Areas of the Tooele Army Depot. Geophysical survey results, data from wells and borings, and topographical and geological information were used to determine the hydrogeologic systems discussed in the following sections. An example of data obtained during the field drilling program is shown in Figure 9. Because of the complexity of the ground-water systems and the small number of data



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TOOELE ARMY DEPOT

LITHOLOGY AND WELL DESIGN
WELLS N-8A AND N-8B

6-82

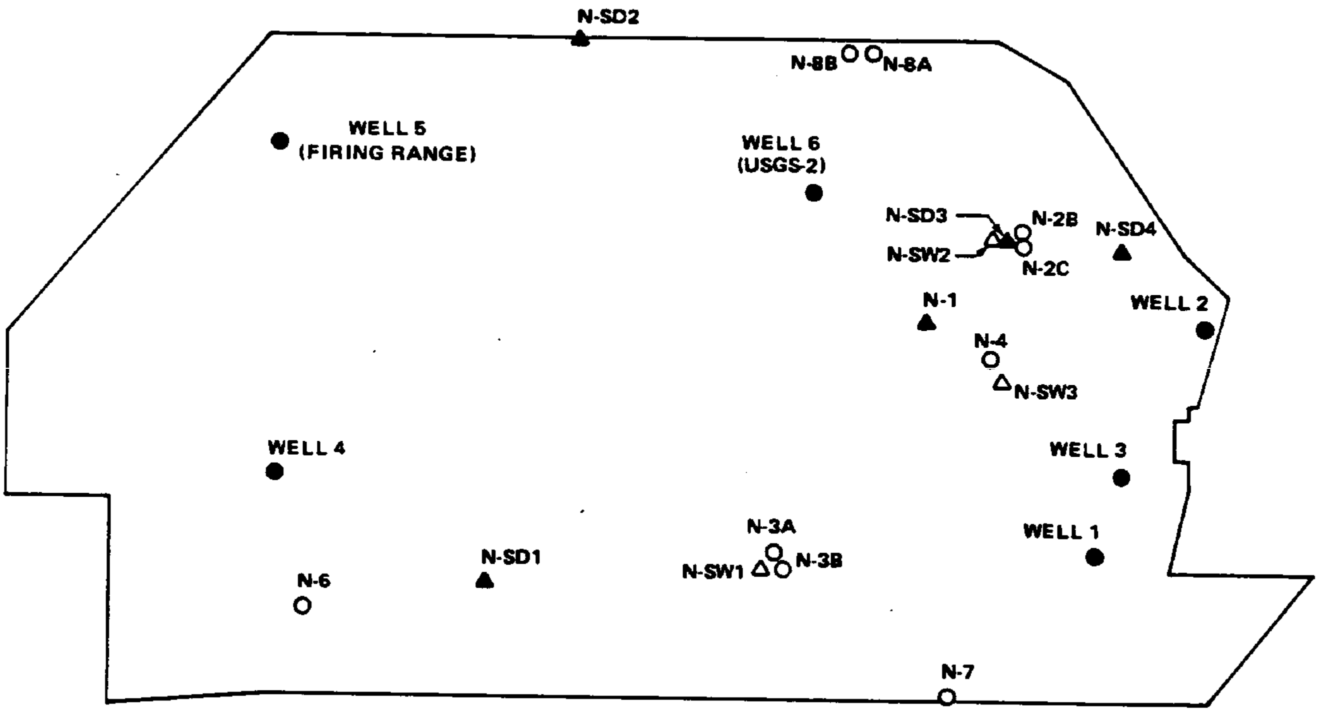
FIGURE 9

points, it is possible to arrive at different interpretations, all equally valid, using the same data set. This is particularly true in the South Area. Figures 10 and 11 show the locations of the drilling and sampling activities for the North and South Area.

The occurrence, movement, and nature of the ground-water systems along with possible perched water tables, mounded conditions, recharge and discharge are discussed on a regional and local basis in the following sections.

5.3.1 Regional Hydrogeology

The ground-water flow systems at both the North and South Areas of TEAD are parts of a larger regional system that includes Rush Valley and Tooele Valley. Figure 12 illustrates this regional flow system and shows general directions of ground-water movement. As in all ground-water systems, water moves from areas of recharge to areas of discharge. The recharge areas in this regional flow system lie along the edges of the valleys. Recharge occurs principally from the loss of water from streams that originate in the mountain ranges surrounding the valleys. These streams typically disappear as they travel across the coalesced colluvial fans that slope from the mountain front towards the center of the valleys. Typical of such a stream is Ophir Creek which enters the South Area near its northeast corner. Recharge from mountain streams may also be concentrated along narrow zones where basin boundary faults cut across the colluvial fans. An example of this is found along the north trending boundary fault that occurs just to the east of the entrance to the North Area. Examination of aerial photographs shows that the drainage pattern typical of alluvial fans has been abruptly terminated along this fault.



EXPLANATION

- △ SURFACE WATER SAMPLE LOCATION
- ▲ SEDIMENT SAMPLE LOCATION
- ○ ERTEC WELL OR BORING LOCATION
- ● EXISTING WELL LOCATION

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LOCATION OF DRILLING AND SAMPLING ACTIVITIES, NORTH AREA

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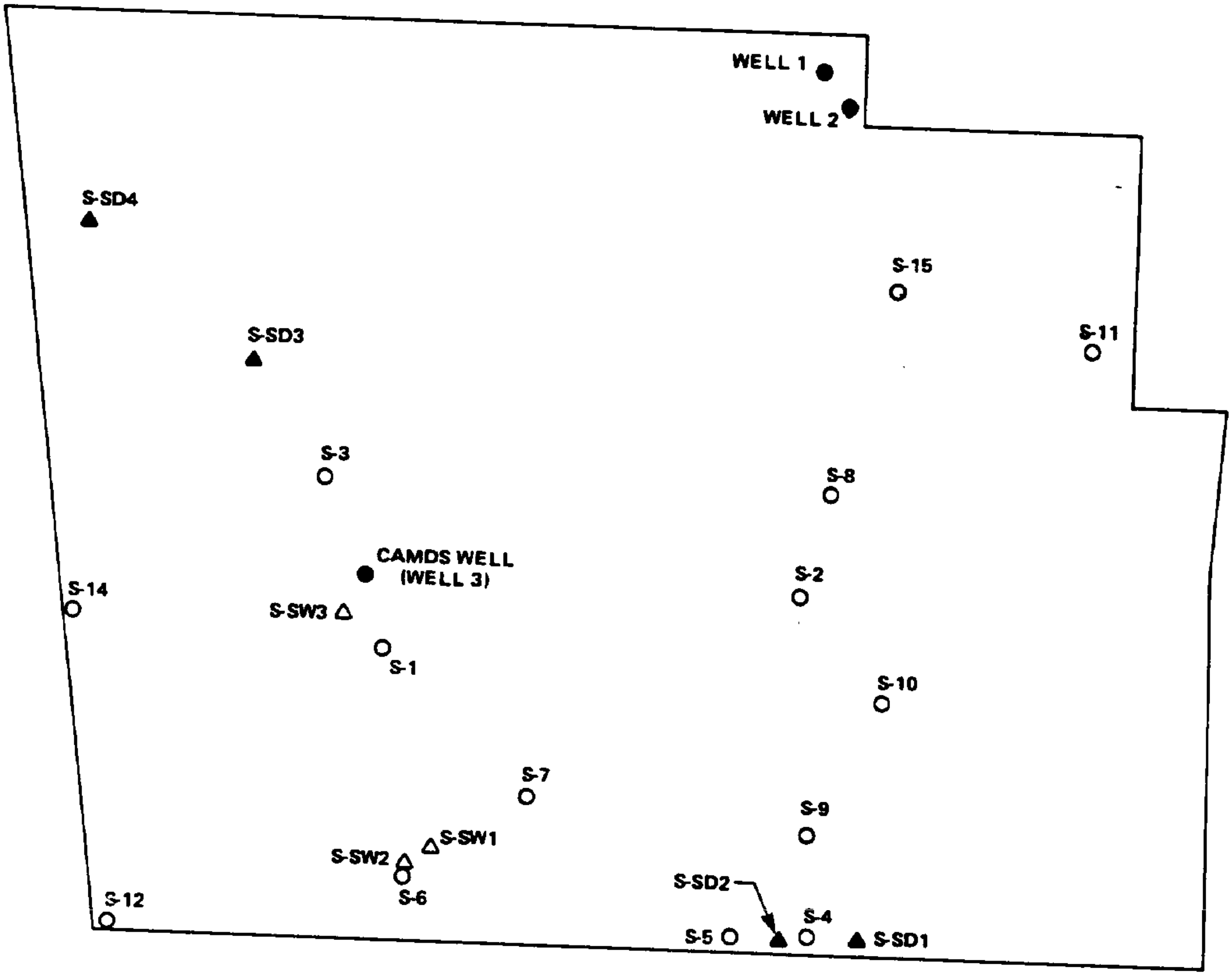
FIGURE 10



EXPLANATION

△ SURFACE WATER SAMPLE LOCATION
▲ SEDIMENT SAMPLE LOCATION
○ ERTEC WELL OR BORING LOCATION
● EXISTING WELL LOCATION

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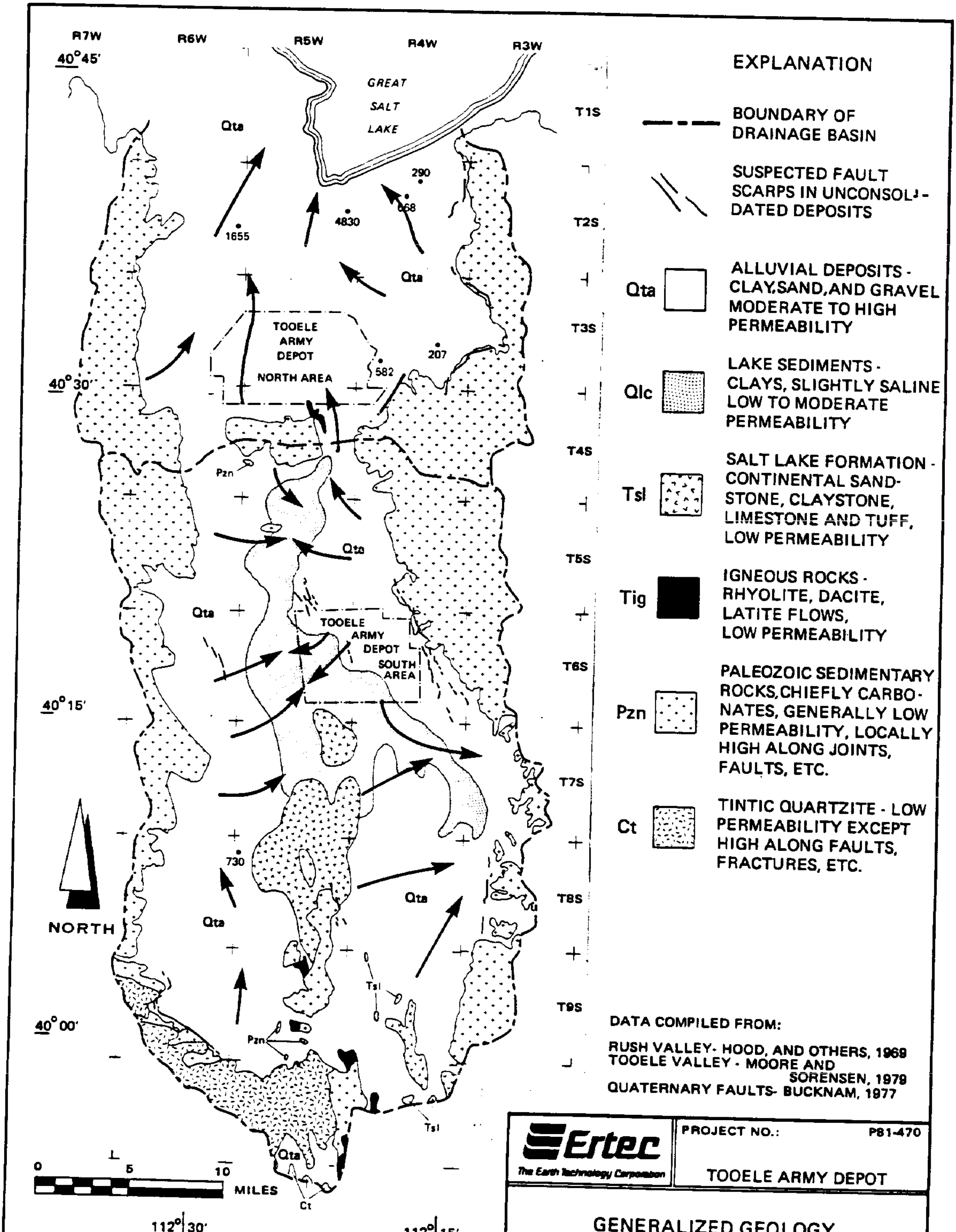
LOCATION OF DRILLING AND SAMPLING ACTIVITIES, SOUTH AREA

7-82

FIGURE 11



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TOOELE ARMY DEPOT

GENERALIZED GEOLOGY,
TOOELE AND RUSH VALLEYS, UTAH

7-81

FIGURE 12

Discharge areas for the regional flow system are of two types. Discharge may occur to adjacent flow systems through connected alluvial valleys. An example of this is the discharge of about 5000 acre feet per year (Razem and Steiger, 1981) from the Rush Valley to the Tooele Valley under the Stockton Bar. The other major type of discharge area for the regional flow system occurs in the low portions of the valleys where water is discharged to evapotranspiration and surface water bodies. Discharge to evapotranspiration occurs in the low part of Rush Valley along the southwest boundary of the South Area. Discharge to Rush Lake in the north end of Rush Valley may also occur seasonally. This lake probably serves both as a recharge and a discharge area. Recharge occurs when surface runoff collects in the lake. Discharge may occur when surface water is not present and any recharge mound from infiltration surface water has dissipated. The major discharge area for the ground-water system in the Tooele Valley is the Great Salt Lake.

The general movement of ground water within the North and South Areas at TEAD is controlled by the regional recharge and discharge described above. Superposed upon the regional features, however, are local sources and sinks of water that are important in the local movement of ground water and contaminants. The following sections describe the conceptual models of these local systems based upon existing data and data collected during the environmental assessment. The relationship of the local flow systems to the regional system is described to the extent possible with the limited number of control points available.

The contamination assessment used in the TEAD program was designed primarily to detect the presence of contaminants in the vicinity of suspected sources.

Consequently, the areal coverage provided by test borings and wells was limited to areas that had high scores in the hazard ranking described in Section 3.0. Because of this, no new information was obtained in the central portion of the North Area and the northwest portion of the South Area. For similar reasons, drilling was not used to obtain data concerning the vertical nature of the hydrogeologic systems below the regional water table. Inferences and conclusions about the thickness of saturated materials, configuration of the top of the Paleozoic carbonate bedrock, and local flow patterns are therefore based on data from the seismic refraction, gravity and electrical resistivity surveys, supplemented with logs of existing wells and test holes.

Detailed understanding of the local flow systems and their relationships to the regional systems must await more detailed exploration using drilling and surface geophysics.

The following sections discuss the hydrogeology of the North and South Areas of TEAD in terms of the materials comprising the aquifers; the occurrence of ground water under confined, unconfined and perched conditions; the regional and local directions of movement from recharge to discharge areas, both natural and those caused by human activities at TEAD; preliminary estimates of the transmissive properties of the aquifers; and the implications for contaminant movement from sources for which soil materials and/or ground water were found to be contaminated.

5.3.2 Hydrogeology - North Area

Table 2 summarizes the drilling date obtained for the North Area. The aquifers underlying the North Area of TEAD consist of unconsolidated alluvial

TABLE 2. DRILLING SUMMARY

TEAD - NORTH AREA

Bore/Well	Drilling Method	Date Completed	Total Depth	Water Level	# Soil Samples Taken	# Soil Chem Samples	Development Completed	Water Sample Taken	Ground Elevation (feet)
N-2A	auger	1/6	62 feet	dry	13	0	---	---	4679.19
N-2B(b)	cable tool	3/7 capped	65 feet	dry	14	0	---	---	4679.19
N-2C	cable tool	6/11	100 feet	87.9 feet	21	0	6/12	6/24	4681.1
N-3A	rotary	3/8	345 feet	252.5 feet	67	11	3/17	4/5	4723.9
N-3B	rotary	3/8	65 feet	50.9 feet	0	0	6/4	6/23	4724.1
N-4	cable tool	5/25	215.9 feet	191.3 feet	43	0	6/3	6/24	4662.6
N-6	cable tool rotary	2/27	709 feet	dry	143	0	4/20	---	5091.9
N-7(b)	cable tool	2/14 capped	75 feet	dry	15	0	---	---	4853.3
N-8A	auger	1/26	98 feet	dry	20	0	---	---	4471.9
N-8B	rotary	1/26	299 feet	168.9 feet	40	0	2/26	5/3*	4472.3

(b) indicates bore

* 2 samples

and colluvial fan materials, cemented conglomerates or fanglomerates, and Paleozoic carbonates. The unconsolidated alluvial materials overlie either the cemented conglomerates and/or the carbonates. Cross Sections A-A' and B-B' (Figures 13 and 14) illustrate the inferred relationship among the three types of materials in the eastern third of the North Area. These cross sections illustrate the complicated hydrogeology occurring in this area as determined by the use of geophysics, borehole drilling, and existing well logs. This is also the area with the most important of the potential contaminant sources, as determined by the Hazard Ranking System. Movement of contaminants will be discussed in the following sections.

Ground water in the North Area of TEAD occurs under confined, unconfined, perched, and mounded conditions. Figure 15 shows the potentiometric contours of the North Area and illustrates the flow of ground water from the perched zones around the Industrial Waste Pond (Well N-2C) and the TNT Washout Ponds (Well N-3B), and the mounded conditions around the Sewage Lagoon (Well N-4).

As discussed in the following section, a ground-water mound has been established from seepage from the Sewage Lagoon. Well N-4 intercepts this mound about 1200 feet from the lagoon. At this point the top of the mound is approximately 34 feet above the predicted regional ground-water table. Flow lines in Figure 15 show the movement of ground water away from the mounded area.

Two perched zones of limited extent have been located in the North Area. The perched zone existing around the TNT Washout Ponds is produced by the continuous seepage of laundry effluent from a small pond and discharge trench extending several hundred yards north of Well N-3B. This discharge stream is

TABLE 4. Key for Analyte Codes, Tables 5 through 10 and Site Summary Sheets

Analyte	Code
Volatiles (624) (method 2J)	
Benzene	C6H6
Bromomethane	CH3BR
Chlorobenzene	CLC6H5
1,2-Dichloroethane	12DCLE
Trans-1,2-Dichloroethene	T12DCE
1,1,2,2-Tetrachloroethane	TCLEA
1,1,1-Trichloroethane	111TCE
Trichloroethene	TRCLE
Semi-Volatiles (625) (method 3W)	
Hexachloroethane	CL6ET
Naphthalene	NAP
Nitrobenzene	NB
3,5-Dinitroaniline	35DNA
2,Amino-4, 6-DNT	2A46DT
Fluoranthene	FANT
3-Nitrotoluene	3NT
Diethylphthalate	DEP
Alpha-BHC	ABHC
p,p'-DDT	PPDDT
Dieldrin	DLDRN
Lindane	LIN
Heptachlor	HPCL

Analyte	Code
Aroclor-1016	PCB016
Aroclor-1262	PCB262
2,4-Dimethylphenol	24DMPN
2,4-Dinitrophenol	24DNP
2-Methyl-4,6-dinitrophenol	46DN2C
Pentachlorophenol	PCP
Phenol (D6)	PHEND6
<u>Explosives (method 2B)</u>	
2,4-DNT	24DNT
2,6-DNT	26DNT
2,4,6-TNT	246TNT
Tetryl	TETRYL
RDX	RDX
<u>NG & PETN (method 6B)</u>	
Nitroglycerine	NG
PETN	PETN
<u>Metals-ICP (method 3T)</u>	
Arsenic	AS
Beryllium	BE
Cadmium	CD
Chromium	CR
Copper	CU
Lead	PB
Nickel	NI
Silver	AG
Zinc	ZN

Analyte	Code
Metals-GF/AA (method 1T)	
Arsenic	AS
Nickel	NI
Zinc	ZN
Mercury-CV/AA (method 1D)	
Mercury	HG
Sodium (method 1M)	
Sodium	NA
Anions (method 2P)	
Chloride	CL
Fluride	F
Nitrate	NO3
Nitrate	NO2
Phosphate	PO4
Sulfate	SO4
Cyanide (method 4K)	
Cyanide	CYN
Oil & Grease (method 00)	
Oil & Grease	OILGR
Gross Alpha & Beta (method 30)	
Gross Alpha	ALPGL
Gross Beta	BETGL

TABLE 5. ANALYSIS OF ORGANICS IN GROUND WATER AND SURFACE WATER - TEAD NORTH AREA (in $\mu g/1$)

	Volatiles				Semi-Volatiles			Explosives			
	12DCLE	T12DCE	111TCE	TRCLE	24DMPN	46DN2C	PHEND6	246TNT	TETRYL	RDX	Oil/ Grease
N-2C	1.7	1.2	329	1.1	-	-	-	3.09	-	-	-
N-3A	-	-	-	-	-	-	-	-	-	13	-
N-3B	-	-	-	-	-	27	-	-	-	-	-
N-4	-	-	-	1.2	-	-	-	-	-	-	-
N-8B(1)	-	-	-	-	-	-	-	-	-	-	5000+
N-8B(2)	-	-	-	-	-	-	-	-	-	-	-
North No. 1	-	-	-	-	-	-	-	-	-	-	-
North No. 2	-	-	-	-	-	-	-	-	-	-	-
North No. 4	-	-	-	-	-	-	-	-	-	-	-
North No. 5	-	-	-	-	-	-	-	-	-	-	-
North No. 6(USGS)	-	-	-	-	-	-	-	-	-	-	-
N-SW1 (TNT Washout)	-	-	1.8	-	-	-	-	-	-	-	-
N-SW2 (Ind. Waste Pond)	-	-	-	-	2238	-	-	-	2.2	1.9	23000
N-SW3 (Sewage lagoon)	-	-	-	-	-	-	8	-	-	-	-
LOD (water)	1	1	1	1	20	20	3	2	1	1	5000
EPA Water Quality Standards	9.4	-	18400	27	100	-	3500	-	-	-	-

TABLE 6. ANALYSIS OF INORGANICS IN GROUND WATER AND SURFACE WATER - TEAD NORTH AREA (in $\mu g/l$)

	Metals									Anions						Gross Beta Radiation
	AS	NI	ZN	BE	CD	CR	CU	PB	CYN	CL	F	NO_3	PO_4	SO_4	NA	(pCi/1)
N-2C	47	615	69	-	-	40	-	70	-	>16700	1860	-	5300	-	659000	-
N-3A	-	33	38	-	-	11	-	46	-	872100	890+	264200	-	779500	296000	15 $\pm$ 6
N-3B	46	-	69	-	-	8	9	-	-	>16700	6640	22200	-	>18500	251000	15 $\pm$ 3
N-4	-	10	38	-	-	-	-	-	-	>16700	1060	10200	-	>18500	141000	6 $\pm$ 3
N-8B(1)	-	7	13	-	-	19	-	-	-	16700	-	10000	-	18500	200000	-
N-8B(2)	-	6	66	-	-	14	-	-	-	>16700	-	10000	-	>18500	20300	-
North No. 1	-	42	39	-	-	26	-	138	-	195200	-	14400	-	203200	97000	-
North No. 2	-	5	13	-	-	22	-	120	-	>20600	-	2200	-	16500	39000	-
North No. 4	-	7	3	-	-	25	-	137	-	86300	-	10000	-	33000	31600	10 $\pm$ 6
North No. 5	-	26	2	-	-	24	28	142	-	>20600	-	2200	-	16500	26700	-
North No. 6(USGS)	-	15	3	-	-	25	-	145	-	37300	-	10000	-	33000	310000	-
N-SW1 (TNT Washout)	-	8	48	-	-	12	7	41	-	333500	8850	12200	-	222000	19200	-
N-SW2 (Ind. Waste Pond)	-	8	36	0.7	33	322	62	1130	31	>20600	3540	3300	3700	>20400	498000	-
N-SW3 (Sewage lagoon)	-	-	10	-	-	-	14	-	11	>16700	-	-	2800	>18500	196000	8 $\pm$ 3
LOD (water)	7	5	1	0.5	6	5	6	30	10	1000	1000	1000	1000	1000	1000	3.8
Utah Standards	50	-	5000**		-	-	-		-	2.5×10^5**	1600	10000	-	1×10^6	-	-
EPA Water Quality Standards	22.0	13.4	5000	0.037	10	-	1000	50	100	2.5×10^5**	-	1×10^4 as N	-	1×10^6	-	50

** Secondary Standards

TABLE 7. ANALYSIS OF SEDIMENT AND SOIL SAMPLES - TEAD NORTH AREA (in $\mu g/l$)

	Explosives				Metals			Anions					
	24DNT	26DNT	246TNT	RDX	AS	NI	ZN	CL	F	NO_3	PO_4	SO_4	NA
N-SD1	-	-	-	-	-	-	-	-	-	4440	-	1940	3860
N-SD2	-	-	-	-	9	-	12	-	-	-	-	>20400	1780
N-SD3	-	-	-	-	-	9	19	>2060	1010+	-	2760	>20400	14700
N-1 (1.0 ft.)	-	-	-	-	22	11	20	3920	-	>20000	3680	7800	-
N-3A (0.5-1.5')	84	256	31	1024	-	7	8	-	-	3330	1840	970+	1190
N-3A (10'-11.5')	-	-	-	5	-	-	-	-	-	-	-	-	-
N-3A (20'-21.5')	-	-	-	19	-	-	-	-	-	-	-	-	-
N-3A (40'-41.5')	-	-	104	-	-	-	-	-	-	-	-	-	-
N-3A (50'-51.5')	17	-	-	-	-	-	-	-	-	-	-	-	-
N-3A (60'-61.5')	-	-	-	242	-	-	-	-	-	-	-	-	-
N-3A (70'-71.5')	-	-	-	11	-	-	-	-	-	-	-	-	-
N-3A (80'-81.5')	-	-	-	26	-	-	-	-	-	-	-	-	-
N-3A (90'-91.5')	-	-	-	28	-	-	-	-	-	-	-	-	-
LOD (Soil)	10	15	10	5	7	5	1	1000	1000	1000	1000	1000	1000

TABLE 8. ANALYSIS OF GROUND WATER AND SURFACE WATER - TEAD SOUTH AREA (in $\mu g/l$)

	Oil/ Grease	Metals AS	NI	ZN	BE	CR	CU	PB	CYN	Anions CL	F	NO_3	PO_4	SO_4	NA	Gross Alpha (pCi/l)	Gross Beta (pCi/l)
S-1	-	104	-	-	-	-	-	-	12	>16700	1400	3100	-	>18500	$1.64x10^5$	-	28 ± 4
S-2	-	-	-	13	-	-	-	-	-	>16700	-	11100	-	>18500	27200	13 ± 10	-
S-3	-	12	7	63	-	-	-	-	-	>16700	1800	-	-	>18500	$1.41x10^6$	-	9 ± 6
S-4	-	430	-	6	-	-	-	-	-	>16700	1500	-	-	>18500	$1.34x10^6$	-	36 ± 7
S-5	-	166	-	5	-	-	-	-	-	>16700	2400	5300	-	>18500	$1.20x10^6$	-	15 ± 6
S-6	-	111	-	2	-	-	-	-	-	>16700	2660	-	-	>18500	$5.23x10^6$	-	31 ± 7
S-7	-	20	11	12	-	-	-	-	-	>16700	1770	12000	-	>18500	$2.06x10^6$	-	17 ± 6
S-8	-	-	-	9	-	-	-	-	-	>16700	-	>21000	-	>18500	$9.20x10^4$	-	-
S-10	-	-	-	15	-	-	-	-	-	12800	-	8100	-	>18500	$3.07x10^4$	-	-
S-12	-	37	-	-	-	-	-	-	-	>16700	1770	6700	-	>18500	$2.62x10^6$	-	46 ± 8
S-14	5000	8	14	27	-	-	-	-	-	>16700	7400	-	-	>18500	$1.72x10^6$	-	34 ± 7
South No. 1	-	-	8	2	-	19	-	116	-	>37300	-	10000	-	>33000	$1.68x10^4$	-	-
South No. 3 (CAMDS)	-	-	9	2	-	22	6	91	-	>20600	1800	-	-	>20400	$8.97x10^5$	-	-
S-SW1 (Crater)	-	18	7	3	-	26	9	163	-	>34300	-	1100	-	15600	$6.43x10^4$	-	10 ± 6
S-SW2 (Crater)		100	-	-	2.6*	45*	23*	151*	-	20600	2400	-	-	>20400	$4.40x10^6$	29 ± 16	34 ± 7
S-SW3 (CAMDS)	-	-	-	60	-	-	23	-	-	>16700	-	11700	9000	>18500	$2.24x10^5$	25 ± 7	-
LOD (water)	5000	7	5	1	0.5	5	6	30	10	1000	1000	1000	1000	1000	1000	2	3
Utah Standards	-	50	0	5000**	-	-	6	-	-	$2.5x10^5$**	1600	10000	-	$1x10^6$	-	-	-
EPA Water Quality Criteria	-	22.0	13.4	5000	0.37	-	1000	50	-	$2.5x10^5$**	-	$1x10^4$ as N	-	$1x10^6$	-	15	50

* LOD =1 * LOD =10 * LOD =12 * LOD =60

** Secondary Standards

TABLE 9. ANALYSIS OF SEDIMENT AND SOIL SAMPLES - TEAD SOUTH AREA (in µg/l)

	Semivolatiles		Metals			Anions					
	DEP	PHEND6	AS	NI	ZN	CL	F	NO_3	PO_4	SO_4	NA
S-SD1	-	-	9	-	10	-	-	2200	2800	970+	2500
S-SD2	-	-	8	7	44	2900	-	2200	-	970+	23700
S-SD3	-	-	11	-	7	3900	-	2200	-	1940+	13800
S-SD4	-	-	31	33	66	>20600	-	-	-	>20400	49500
S-1 (5'-6.5')	12	-	33	9	7	>19600	-	-	-	>20400	23100
S-1 (10'-11.2')	17	-	25	-	16	>19600	-	-	-	16500	48500
S-1 (15'-15.7')	-	-	37	-	5	>19600	-	-	-	19400	39600
S-1 (20.2'-21.2')	11	-	98	-	8	>19600	1300	-	-	20400	45500
S-2 (5'-6')	-	15	-	-	2.2	252000	-	11100	-	-	199800
S-2 (25'-25.6')	-	-	-	-	3	162000	-	7800	-	-	21600
S-2 (45'-46.5')	-	-	-	-	2	101000	-	6700	-	-	6780
S-8 (15'-16.4')	-	30	9	7	4	1960	-	-	-	5800	41500
S-8 (40'-41.5')	-	-	42	47	7	19600	890+	1110+	-	8700	17800
S-8 (55'-56.5')	-	15	26	-	4	1960	-	-	-	-	24700
S-8 (65'-66.1')	-	-	-	-	5	16700	-	1100+	-	4900	18800
S-8 (80'-81.1')	9+	-	-	-	45	8800	-	3300	-	-	6900
S-11 (17'-17.9')	-	207	-	-	2	111000	-	4400	-	23300	102800
S-11 (36.5'-37')	-	11+	-	-	2	42200	-	2200	-	4900	18400
S-11 (76'-76.5')	-	-	-	-	-	5900	-	-	-	3900	5050
LOD (Soil)	10	15	7	5	1	1000	1000	1000	1000	1000	1000

TABLE 10. Contaminants Analyzed but not Detected in any Samples at TEAD

Contaminant	LOD (μg/L) Water	LOD (μg/L) Soil Leach	Standard (μg/L) Utah	Standard (μg/L) EPA
C6H6	1	-	-	6.6
CH3BR	1	-	-	1.9
CLC6H5	1	-	-	4.88
TCLEA	1	-	-	1.7
CL6ET	20	100	-	-
NAP	2	10	-	-
NB	8	40	-	-
35DNA	20	100	-	-
2A46DT	20	100	-	-
FANT	2	10	-	42
3NT	10	50	-	-
ABHC	20	100	-	0.092
PPDDT	2	10	-	-
DLDRN	2	10	-	-
LIN	20	100	-	0.186
HPCL	8	40	-	0.278
PCB016	70	350	-	7.9×10^{-4}
PCB262	100	500	-	7.9×10^{-4}
24DNP	30	150	-	-
PCP	20	100	-	1010
NG	20	100	-	-
PETN	5	25	-	-
AG	8	40	-	-
HG	0.2	1	2	0.144
NO2	1000	1000	-	-

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SITE SUMMARY SHEET — TOOELE ARMY DEPOT

SITE IDENTIFICATION N-4

SITE TYPE Well

SCREENED INTERVAL 193.1 to 208 feet

DEPTH TO WATER (FEET) 191.3 feet

GROUND ELEVATION (FEET) 4662.6

LOCATION 801,178.63 Northing; 1,759,476.34 Easting (Utah State Plane, Central Zone)

REASON FOR SAMPLING Well N-4 is located 1200 feet north-northwest of the sewage lagoon. It is re-located and combined with N-1. Sampled to determine if contaminants in ground-water from sewage lagoon and landfill sources. High value in Hazard Ranking System.

FIELD SAMPLE NUMBER	SAMPLE DEPTH (FEET)	SAMPLE TYPE	SAMPLE METHOD	DATE SAMPLED	CHEMICAL CONSTITUENTS (ABOVE LOD)
N-4	196	ground water	pump	6/24/82	Cl, F, NO_3, SO_4, Na, Gross beta
					Ni, Zn, TRCLE

EXAMPLE SITE SUMMARY SHEET

FIGURE 17

TABLE 11. MEASURED FIELD PARAMETERS DURING WATER SAMPLING

Sample	Temperature (°C)	pH	Eh (Mv.)	Specific Conductivity (µmhos/cm t 25°C)	Date of Sample
North Area					
Well 1	15	7.19	+406	1700	3/30/82
Well 2	14	7.55	+495	660	3/30/82
Well 4	17	7.34	+430	520	3/31/82
Well 5	18	7.46	+437	590	4/14/82
Well 6	18	7.32	+389	1750	4/04/82
N-2C	17	7.02	-30	2400	6/24/82
N-3A	14	7.10	+371	5500	4/05/82
N-3B	17	7.02	+422	2000	6/23/82
N-4	16	7.03	+313	1950	6/24/82
N-8B(1)	17	7.04	+385	2000	5/03/82
N-8B(2)	17	7.03	+409	2000	5/3/82
N-SW1	24	8.65	+374	2150	4/05/82
N-SW2	17	9.9	+290	2250	4/14/82
N-SW3	17	7.00	+349	2000	6/23/82

TABLE 11 MEASURED FIELD PARAMETERS DURING WATER SAMPLING (Cont'd)

Sample	Temperature (°C)	pH	Eh (Mv.)	Specific Conductivity (μmhos/cm @ 25°C)	Date of Sample
South Area					
Well 1	11	7.30	+453	680	3/31/82
Well 3	13	8.08	+234	2950	4/15/82
S-1	15	7.05	+341	12000	6/24/82
S-2	15	7.03	+436	440	4/29/82
S-3	13	6.81	+367	11000	4/29/82
S-4	13	7.05	+433	10000	5/02/82
S-5	15	7.05	+366	13000	5/02/82
S-6	15	7.11	+381	27000	4/28/82
S-7	13	7.02	+402	16000	5/04/82
S-8	13.5	7.06	+412	1600	5/04/82
S-10	15	7.10	+376	380	5/02/82
S-12	15	7.20	+461	18000	4/28/82
S-14	13.5	7.03	+297	55000	5/02/82
S-SW1	5	8.53	+442	450	4/06/82
S-SW2	11	8.28	+353	21000	4/15/82
S-SW3	22	7.03	+316	1200	5/04/82

Sewage Lagoon and Industrial Waste Pond have been considered as one problem study area, hereafter called the Headquarters Area, because of their proximity and possible interactions. Likewise, the TNT Washout Ponds area includes the Laundry Ponds and discharge.

In the South Area, the problem of relatively high arsenic levels covers a much wider area and can not readily be associated with a particular source. These three problem areas are discussed in detail in the following sections.

5.5.1 Headquarters Area

In the Environmental Assessment, Ertec hypothesized the presence of a buried bedrock ridge running from the northeast corner of the North Area to the south-central boundary, as shown in Figure 1. Evidence of this buried ridge was obtained from several site visits during which the dip, strike, and composition of the bedrock outcrop in the northeast corner was noted and a subsequent outcrop found near the south-central boundary having approximately the same dip, strike and composition. From knowledge of tectonics and Basin and Range physiography, it was realized that a buried bedrock ridge could exist connecting these two outcrops. This is typical of Basin and Range valleys where huge down-faulted blocks of Paleozoic carbonates are common. This type of geologic feature, as close as it is to several sources of potential contamination which were identified as being extremely important by our Hazard Ranking System, would have an important influence on the movement of the regional ground-water system, and on the perched ground water resulting from recharge of contaminated water from the Industrial Pond and Sewage Lagoon.

Based upon the gravity survey, the presence of a bedrock high trending almost due south from the outcrop was confirmed.

The location of Well N-2C was based upon the results obtained from the geophysical surveys and a water balance for the Industrial Waste Pond which showed [redacted]. This well penetrated a perched zone at a depth of about 95 feet. Ground-water flow in this zone is suspected to be south and southwest, along the bedrock surface (Figure 13), at approximately right angles to the regional flow.

The geophysical surveys provided the basis upon which to reduce the number of wells necessary in this area. Upon examining the cross-sections and maps produced from the geophysical surveys, it was decided that it was not necessary to drill both Wells N-1 and N-4 in this area. By using the maps produced, Ertec was able to relocate Well N-4 to a more advantageous position and eliminate Well N-1 entirely.

The depth to water in Well N-4 was found to be approximately 100 feet higher than the expected level of the regional water table as shown in the Technical Plan. Based upon the potentiometric map prepared using additional water level data from this study (Figure 15), the mound was found to be approximately 34 feet higher than the expected regional water table. A water balance was then conducted for the Sewage Lagoon to determine the amount of water available to cause such a ground-water mound at Well N-4, about 1200 feet from the Sewage Lagoon. From TEAD records, it was determined that approximately [redacted]000 gallons per day are being added to the Sewage Lagoon (Table 12), of which approximately [redacted] gallons per day are being lost as infiltration. Using equations developed by Hantush (1967), it was determined that a 34 feet high

Table 12. Inflow to Sewage Lagoon

(Recorded by Facilities Engineering Division)

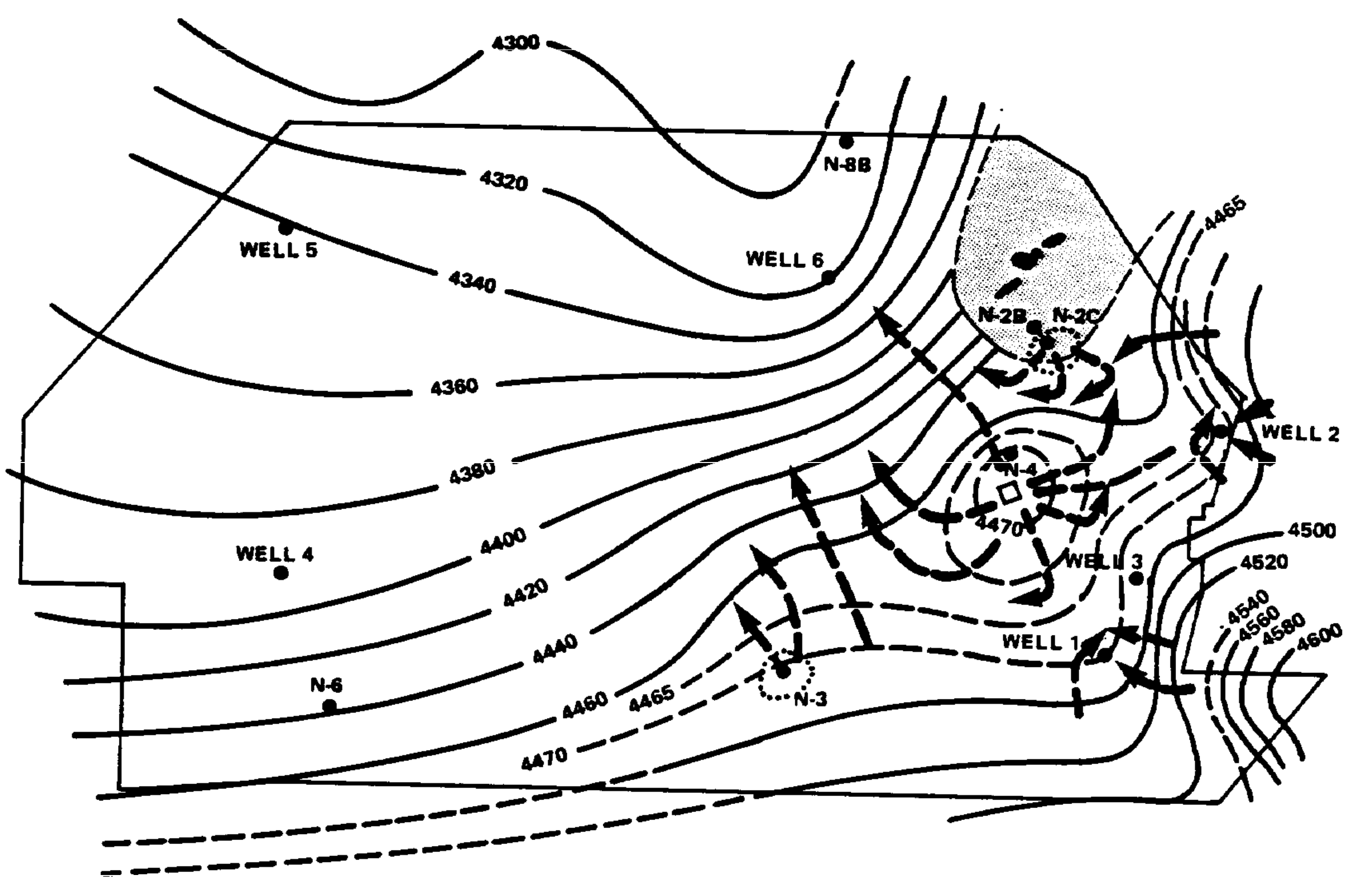
January 1980	2,340,000 gallons per month
February	2,308,000 gallons per month
March	2,390,000 gallons per month
April	2,802,000 gallons per month
May	3,240,000 gallons per month
June	2,772,000 gallons per month
July	3,416,000 gallons per month
August	3,236,000 gallons per month
September	3,968,000 gallons per month
October	2,660,000 gallons per month
November	1,464,000 gallons per month
December	1,704,000 gallons per month
January 1981	1,436,000 gallons per month
February	1,452,000 gallons per month
March	2,236,000 gallons per month
April	2,144,000 gallons per month
May	2,468,000 gallons per month
June	2,492,000 gallons per month
July	2,800,000 gallons per month
August	2,948,000 gallons per month
September	2,708,000 gallons per month
October	2,488,000 gallons per month
November	2,572,000 gallons per month
December	2,864,000 gallons per month
January 1982	2,600,000 gallons per month
February	2,432,000 gallons per month
March	2,736,000 gallons per month
April	2,928,000 gallons per month
May	2,392,000 gallons per month
June	2,716,000 gallons per month
	76,712,000

$\overline{X}$ = 2,557,000 gallons per month
SD = 562,000

Water Balance

inflow:	2,557,000 gal/mo	= 11,200 ft^3/day
area:	520 ft x 620 ft.	= 322,400 square feet
precipitation:	16.5 in./yr	= 1214 ft^3/day
evaporation:	42 in./yr	= 3089 ft^3/day

seepage = inflow + precipitation - evapotranspiration
seepage = 9356 ft^3/day = 48 gal/min



PERCHED WATER

PALEOZOIC CARBONATES ABOVE THE WATER TABLE

REPRESENTATIVE FLOW LINES

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TOOELE ARMY DEPOT

NORTH AREA POTENTIOMETRIC SURFACE AND REPRESENTATIVE FLOW LINES

9-82

FIGURE 15

irregular and its course has changed several times in the past. The seepage of this effluent into the ground water has been hypothesized as the mechanism for carrying explosives to the regional flow system. This is discussed more fully in the following sections. The movement of water from this perched zone is to the north-northwest and is shown in Figure 15.

A more complicated perched system occurs around the Industrial Waste Pond. Seepage of waste water from this pond, as discussed in following sections, flows into the unconsolidated alluvium, the cemented conglomerate, and the underlying carbonate bedrock ridge in this area. Through the geophysical surveys and several borings and wells around this pond, Ertec has determined that water in this perched zone flows opposite regional flow, i.e., to the southeast and south, until it intercepts the regional flow and is carried northwest (see Figure 15). The lateral extent of this zone has not been determined. Contaminated water of the perched zone that intercepts the carbonate bedrock may carry pollutants 10 to 100 times further than in the surrounding unconsolidated sediments because of fractures and solution channels that commonly exist in this type of material. This type of ground-water movement is extremely difficult to assess. Cross Sections A-A' and B-B' further illustrate the hydrogeologic conditions in this area.

The general flow of ground water through the North Area is towards the north as shown in Figure 15. This movement occurs principally as unconfined ground-water flow through the upper portion of the valley fill materials. Confined conditions probably exist in materials at depth under the North Area. This flow pattern is distorted by recharge from the east along the Oquirrh Mountains. Recharge water flowing west onto the Depot is "stacked up" behind the less permeable carbonate ridge until it gradually flows to the north and the contours flatten out as shown in Figure 15. Additional recharge occurs from South Mountain with water flowing to the north and gradually to the northeast. This recharge area extends at times onto the Depot in the vicinity of the Chemical Range and Demolition Areas. This occurs at peak precipitation periods when there is flow in Box Elder Wash. Although there is a possibility that this recharge provides a mechanism for carrying contaminants from the Chemical Range and Demolition Areas into the ground-water system, Ertec believes that this is extremely unlikely due to the depth (greater than 700 feet) of water, the high evapotranspiration of the area, and the low transmissivity of the aquifer at this point. This aquifer is believed to be under confined conditions in this area, with artesian pressure providing the apparently high potentiometric surface occurring in the southwest portion of the TEAD North Area.

Further distortion of the regional flow through the North Area is caused by the pumping of water supply Wells 1 and 2. The cones of depression produced by the pumping of these two wells over a period of time has caused the potentiometric surface distortion as shown in Figure 15. These wells tap the unconsolidated water table aquifer and are pumped periodically throughout the day at their rated combined capacities of approximately 560 gallons per minute (gpm). Continued or prolonged pumping may cause further depression of the water table in this area. The effect of such pumping on contaminant migration is discussed in Section 5.5.

Additional ground-water discharge by large irrigation wells occurs immediately to the northwest of the northern boundary. These wells are pumped in summer months and their effect on the hydrogeology of the TEAD North Area has not been determined.

5.3.3 Hydrogeology -- South Area

Table 3 summarizes the drilling data obtained for the South Area. Shallow ground water in the TEAD South Area occurs generally under unconfined conditions with local areas of confined conditions. The potentiometric contours and direction of ground-water flow as determined from water levels measured in wells tapping the first few feet of the aquifer are shown in Figure 16.

Recharge to the South Area ground-water system occurs from both the northeast and the west. Ophir Creek is an intermittent stream which enters the Depot property in the northeast corner and disappears into the alluvium near Ammunition Storage and Igloos Area 9. This is the only perennial surface-water flow which enters the South Area and which recharges the ground-water system. Water derived from rainfall on and snowmelt from the Oquirrh Mountains is the principal source of recharge to the alluvial fans bounding the eastern side of the Depot. Ground-water also enters the southwestern and western portion of the Depot property as recharge from the Onaqui Mountains.

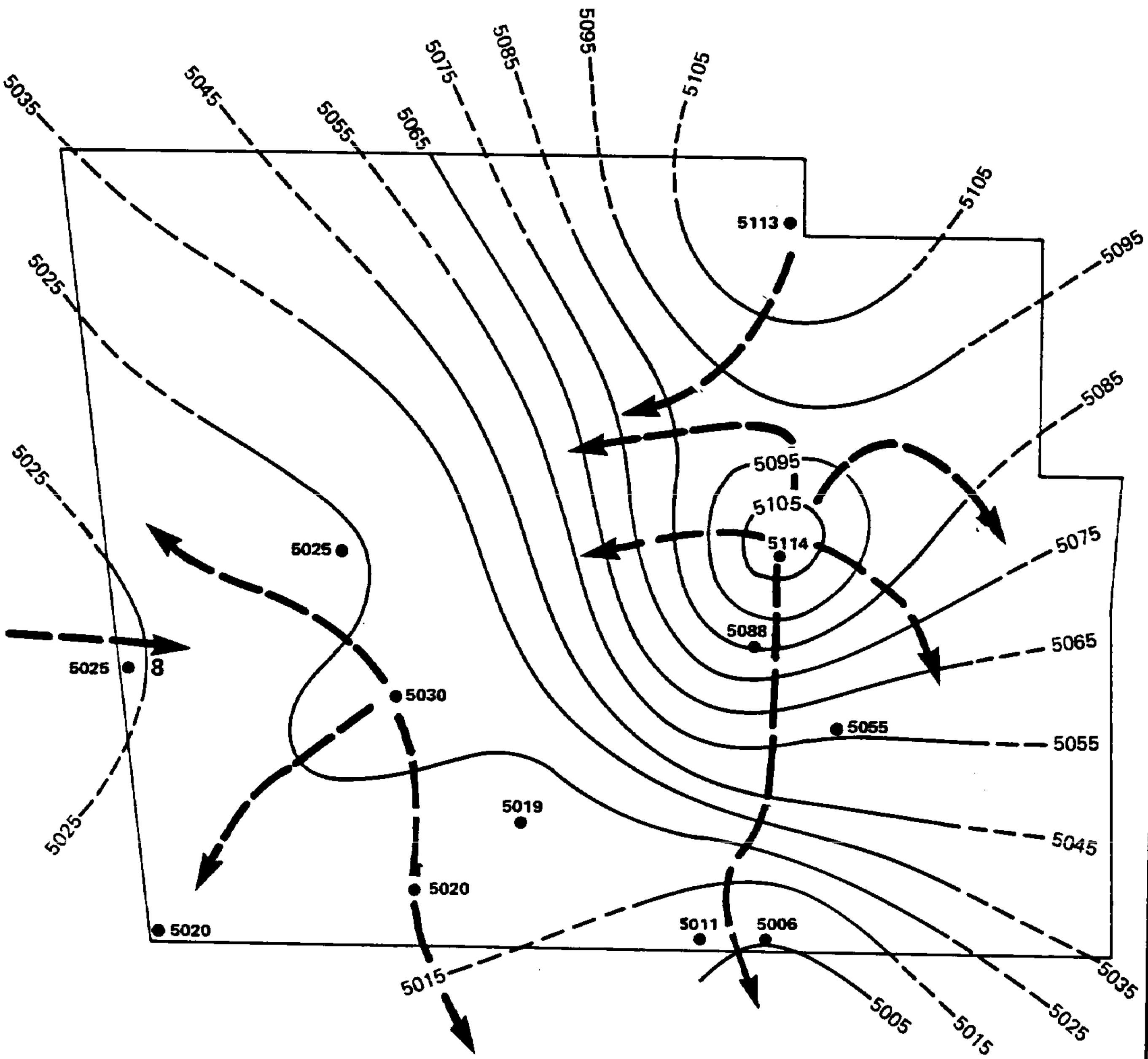
The southern and southwestern part of the Depot is a discharge area for the ground-water system. Ground water from both the northeast and the west flows into this area and is discharged by evapotranspiration. This area has the lowest topographic elevation on the Depot. Flooding of this area occurs during spring snowmelt causing saturated conditions to extend nearly to the land surface. The depth to water in this area is very shallow, ranging from 8 feet at Well S-1 to 58 feet at Well S-4. Ground water from wells drilled in the southern and southwestern areas of the Depot has very high electrical conductivity, ranging from 10,000 μmhos/cm @ 25°C (Well S-4) to 54,000 μmhos/cm @ 25°C (Well S-14). A table is included in Section 5.4 which lists the field

Table 3. Drilling Summary

TEAD - SOUTH AREA

Bore/Well	Drilling Method	Date Completed	Total Depth	Water Level	# Soil Samples Taken	# Soil Chem Samples	Development Completed	Water Sample Taken	Ground Elevation (Feet)
S-1	cable tool	5/27	26 feet	8.0 feet	6	4	6/1	6/24	5038*
S-2	auger	2/19	86.5 feet	57.8 feet	18	3	4/20	4/29	5145.6
S-3	auger	2/9	56 feet	26.85 feet	12	0	4/18	4/29	5051.3
S-4	auger	1/22	91 feet	58.3 feet	19	0	4/20	5/2	5064.0
S-5	auger	1/22	71.5 feet	37.95 feet	15	0	4/18	5/2	5048.6
S-6	auger	2/11	46 feet	17.3 feet	11	0	4/19	4/28	5036.9
S-7	auger	2/10	71 feet	26.5 feet	15	0	4/20	5/4	5045.9
S-8	auger	3/5	100 feet	73.9 feet	21	5	4/20	5/4	5187.4
S-9(b)	auger	2/12 capped	111 feet	dry	23	0	---	---	5098.1
S-10	auger	2/1	101 feet	67.7 feet	21	0	4/19	5/2	5122.5
S-11(b)	auger	2/22	81 feet	dry	19	3	---	---	5350.2
S-12	auger	1/23	45.5 feet	31 feet	9	0	4/20	4/28	5051.1
S-14	auger	1/30	45 feet	10.65 feet	14	0	4/18	5/2	5035.9
S-15(b)	auger	2/20	37 feet	dry	7	0	---	---	5311.8

(b) indicates bore
* approximate



EXPLANATION

5075 WATER LEVEL ELEVATION, FEET

DIRECTION OF FLOW

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TOOELE ARMY DEPOT

SOUTH AREA POTENTIOMETRIC SURFACE AND REPRESENTATIVE FLOW LINES

FIGURE 16

parameters measured during water sampling. The high electrical conductivities are probably the result of dissolution of soluble inorganic constituents found in the alkaline playa soils, concentration of these constituents by evapotranspiration, and stagnation caused by slow moving ground water in areas of low permeability.

The South Area's water supply is obtained from Wells 1 and 2, located in the northeastern corner of the Depot. Well 1 provides most of the water supply and because it is pumping most of the time, its water level altitude was not used in the compilation of the potentiometric surface map. The areal extent of the cone of depression around Well 1 is unknown because of a lack of any additional well data from this area. Ophir Creek runs between Well 1 and Well 2, and probably provides recharge by leakage to the aquifer; this probably reduces the areal extent of the cone of depression caused by pumping either of these wells. The water level elevation data from Well 2 was included in Figure 16. The depth to water in this well is 285 feet. According to lithologic logs (Hood et al, 1969) ground water is probably under water table conditions in this area.

Figure 16 shows a small ground-water mound in the vicinity of Well S-8. Well S-8 was drilled along a drainage ditch containing effluent from Building 553. Infiltration from this ditch may have caused mounding of approximately five feet. The amount of effluent discharged in this area is not known. Water may be mounded above sediments of low permeability which do not allow rapid mound dissipation. Well S-8 is constructed in sediments of very low permeability as evidenced by the fact that the well was repeatedly bailed dry during development and recovered very slowly.

A mound of approximately five feet is also located at Well S-1, near the CAMDS facility. Well S-1 was drilled near the end of the drainage ditch which receives effluent from CAMDS and surface run-off from the south and southeast. Standing water was frequently observed at the end of the ditch, and the entire area was completely flooded throughout the early spring months of 1982. Depth to water was eight feet in June 1982. The infiltration of large volumes of standing water combined with the constant discharge of CAMDS effluent has probably caused this mound.

Shallow ground water occurs under water table conditions throughout the remainder of the South Area. Depth to water is fairly shallow (no greater than 68 feet in any of the wells drilled by Ertec during this program) and the aquifer material is sandy silt and clay in all of these wells. One exception is at the site of Boring S-9, which is in the Demilitarization Area/Disposal Pits, north of Wells S-4 and S-5. The boring was terminated at a depth of 110 feet after penetrating a sticky clay layer of unknown thickness. There was no evidence of the water table at this depth. Ground water may occur under confined conditions at this location.

5.4 Results of Laboratory Analyses

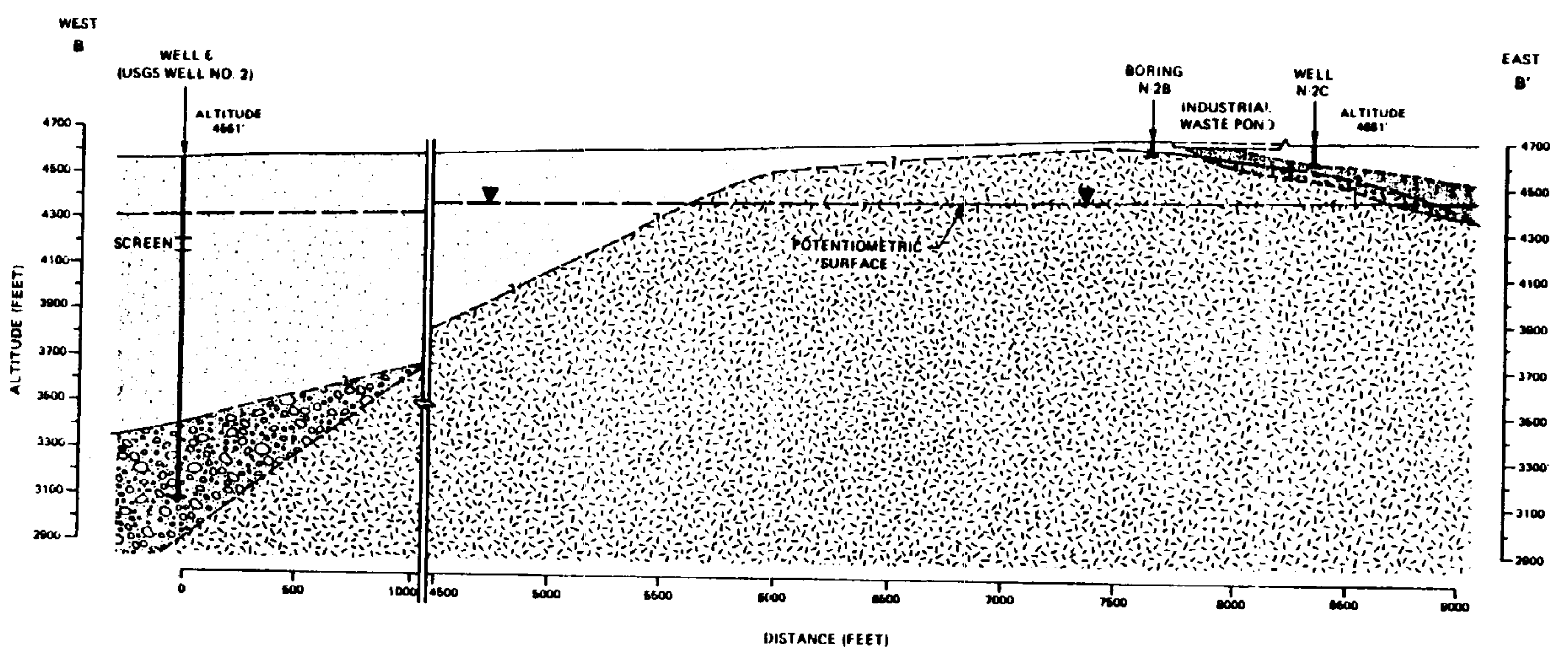
The laboratory has analyzed samples for a total of 46 potential contaminants in soil and sediment and 55 potential contaminants in surface- and groundwater as follows:

Soil and Sediment

20 semi-volatiles
7 explosives
11 metals (cations)
6 anions
2 radiological

Surface and Ground Water

20 semi-volatiles
7 explosives
10 metals (cations)
6 anions
2 radiological
8 volatiles
1 grease and oil
1 cyanide



EXPLANATION

ALLUVIUM

CEMENTED CONGLOMERATE

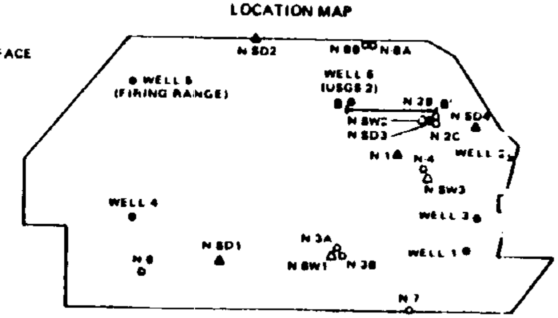
PALEOZOIC CARBONATES

APPROXIMATE ZONE OF GROUND-WATER CONTAMINATION

POTENTIOMETRIC SURFACE

NOTE NO VERTICAL EXAGGERATION

LOCATION MAP



Ertec	PROJECT NO	82 160
	TOOELE ARMY DEPOT	
	CROSS SECTION B-B'	
	Figure 14	

Thirty six soil and sediment samples and 30 surface- and ground-water samples were collected for analysis. In the North Area, 31 total samples were collected; 35 total samples were collected in the South Area. The results of the analyses have been entered into USATHAMA Tier 1 computer files as described in Section 5.6 and are summarized here for convenience in Tables 4 through 9. These tables show semi-quantitative results along with limits of detection (LOD's) and standards for comparison. Contaminants for which analyses were run but which were not found above the LOD in any sample are listed in Table 10.

Summary sheets for each sampling site are in Appendix E. Figure 17, an example site summary sheet, illustrates the information included for each sampling site.

Physical and chemical parameters also were measured in the field during sample collection. These parameters are useful in relating analytes to actual field conditions under which they normally exist. For example, under given pH and Eh conditions it is possible to determine whether an analyte such as nitrate is actually in the form of nitrate or nitrite under in situ conditions. Table 11 lists parameters measured in the field at the time of sampling.

5.5 Problem Areas of Potential Contamination

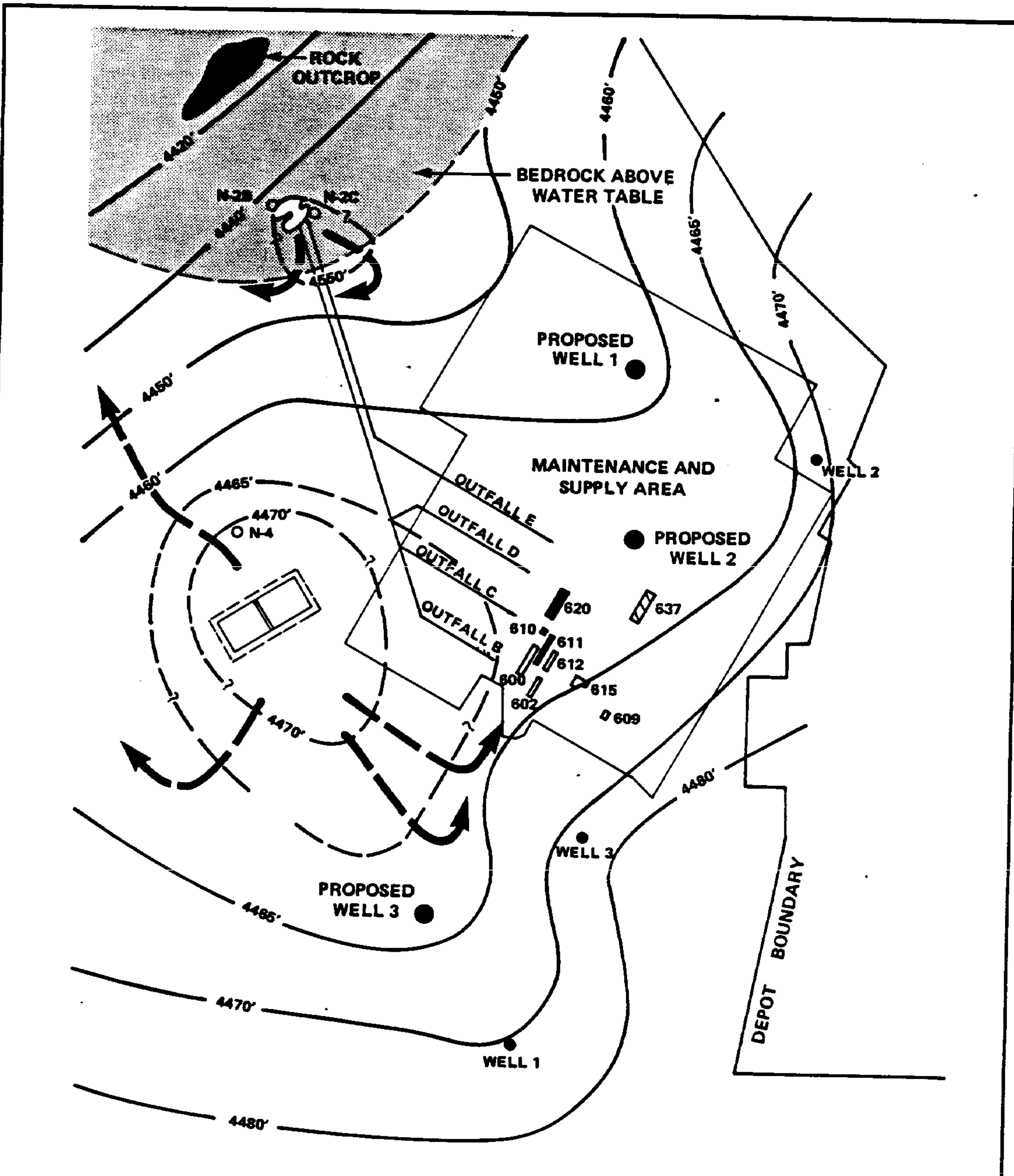
Ertec has identified several source areas where contaminants have been found in pathways which enable migration toward Depot boundaries and/or which pose possible health threats to Depot personnel. These sources include the Industrial Waste Pond (including outfalls and ditches), the Sewage Lagoon, and the TNT Washout Ponds and Laundry Effluent, in the North Area of TEAD. The ground-water mound at Well N-4 is likely, assuming a transmissivity between 30 and 300 ft^2/day which is considered to be reasonable for the cemented conglomerate underlying the alluvium. Cross-sections have been drawn from Well N-2C to Well N-4 and from Well N-2C to Well 6 (USGS Well 2) as shown in Figures 13 and 14. Figure 18, an enlargement of the Potentiometric Map (Figure 15) shows this area in detail.

Contaminated water has the potential to migrate to existing water supply Wells 1 and 2 which provide almost all of the potable water for the TEAD North Area. In addition, contaminants are present in a pathway which has the potential to carry the contaminants across the Depot boundary. Travel time has been calculated to be approximately 55 years from the time contaminants initially reached the aquifer. The contaminated water comes from the two major sources identified by Ertec's Hazard Ranking System -- the Industrial Waste Pond and the Sewage Lagoon.

5.5.1.1 Sewage Lagoon

From data obtained from Well N-4 and from the water balance analysis discussed above, Ertec has determined that the mounded ground-water condition created by seepage from the Sewage Lagoon may pose a possible health threat to users of existing water supply Well 1. The ground-water contours shown on Figures 15 and 18 indicate significant depression of the potentiometric surface, as a result of pumping Well 1. Continued or prolonged pumping of this well may lower the potentiometric surface enough to possibly cause contaminated water from the ground-water mound to be pulled into the well. Chemical analysis of the sewage lagoon wastewater indicates that phenol, arsenic, zinc, copper, cyanide, chloride, phosphate, sulfate, gross beta radiation, and sodium are above the LOD. None of these approach the EPA Water Quality Standards, with

Limit of Detection



BUILDINGS

TO LINE B

TO LINE C

TO LINES D & E

DIRECTION OF GROUND-WATER FLOW

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TOOELE ARMY DEPOT

CONFIGURATION OF WATER TABLE IN HEADQUARTERS AREA

FIGURE 18

the possible exception of arsenic. It should be noted that no nitrates were discovered in the Sewage Lagoon water. This study did not include bacteriological analyses which might provide a more definitive indication of possible contamination in this area.

Chemical analysis of water from Well N-4, with the screened interval in the recharge mound built up from Sewage Lagoon seepage, indicates that nickel, zinc, chloride, fluoride, nitrate, sulfate, gross beta radiation, sodium, and trichloroethene exceed the LOD, and nickel and nitrates approach the EPA Water Quality Standards. Chemical analysis of water from existing Well 1 indicates relatively high nickel, chromium, and lead, the source of which may be well, pump, or pipe construction materials; relatively high nitrates are also present. Since relatively high nitrates and nickel also were found in Well N-4, this may indicate past contamination of the Sewage Lagoon by these pollutants.

Continued and prolonged pumping of Well 2, which has already caused depression of the regional water table, may eventually cause contaminated water to move towards this well, and contamination of water pumped from the well may occur. Contamination in this area may be complicated by seepage of contaminated water from the ditches leading to the Industrial Waste Pond. This seepage may have considerably increased the extent of the perched zone in the direction of Well 2. This problem is discussed further in the next section.

5.5.1.2 Industrial Waste Pond

From data obtained for Wells N-2B and N-2C, the seismic studies, and a water balance analysis of the Industrial Waste Pond, Ertec has determined that a zone exists beneath the pond in which water is perched on the Paleozoic carbonate bedrock. The water which is perched here is [redacted], [redacted], [redacted], and [redacted] in [redacted] Amounts at or above the LOD have been found for the following contaminants: zinc, chloride, fluoride, phosphate, sodium, 1,2-dichloroethane, trans-1,2-dichloroethene, 1,1,1-trichloroethane, trichloroethene, and 2,4,6-trinitrotoluene (possibly affected by interferences). In addition, water in the Industrial Waste Pond itself is currently contaminated with relatively high amounts of beryllium, cadmium, chromium, lead, grease and oil and 2,4-dimethyl phenol which may eventually reach the groundwater system.

The contaminated water in the perched zone arises from seepage of approximately [redacted] day (56 gallons per minute) of [redacted] waste [redacted] from Buildings 600, 602, 609, 610, 611, 612, 615, 620, and 637 in the Maintenance and Supply Area (AEHA Interim Report 2). The contamination originates from metal cleaning and stripping, steam cleaning, boiler plant waters, dynamometer test cells, and spillage, leaks, and overflow containing oils, solvents (particularly Stoddard solvent), paint, and photographic chemicals. The effluent flows through unlined ditches from four separate outfalls, travelling approximately 1.5 miles before entering the pond. An unknown amount of seepage occurs through these ditches. Measurements of pH in the effluents in these ditches have indicated a wide fluctuation in pH from 2.2 to 11.7. This would cause highly erratic and unpredictable mobility of contaminants in sediments contained in and underlying the ditches (AEHA Interim Report).

Prolonged or continued pumping of existing water supply Well 2 may cause further deformation of the regional potentiometric surface, possibly causing the eventual flow of contaminated water from the Industrial Waste Pond and Sewage Lagoon towards and into Well 2. The existing water quality of Well 2 indicates a relatively high level of lead and chromium, which may be caused by well, pump, and pipe construction materials. If water is pulled into Well 2 from the Industrial Waste Pond perched zone, Well 2 may become unuseable as a potable water supply well. In addition, water pulled towards Well 2 from the existing Sewage Lagoon ground-water mound may be contaminated with seepage from the ditches carrying contaminated water to the Industrial Waste Pond. The mound shown in Figure 18 may actually extend further northeast, depending on the amount of waste water seeping from these ditches.

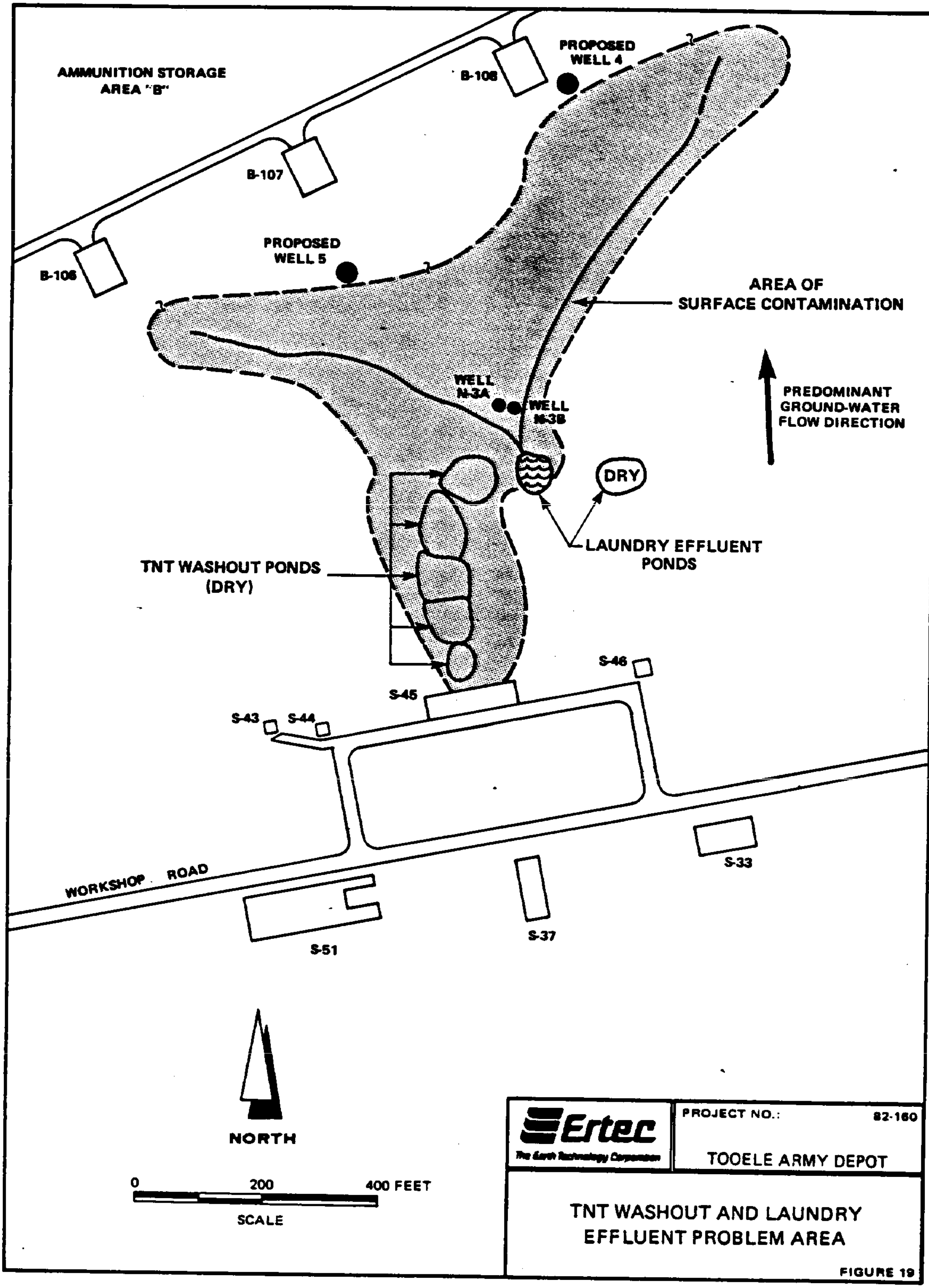
An additional, long-term problem may exist if contaminated water from the Industrial Waste Pond has penetrated the underlying bedrock to any great extent. Figure 13 shows the bedrock configuration and possible contaminant plume penetration. Although the bedrock is a dense, low permeability Paleozoic carbonate, fractures and solution channels may have carried the contamination for much further distances than shown in Figure 13. Contamination of this nature is difficult to assess. If it is sufficiently widespread, it may provide a continuing contaminant source even if the contamination in the Industrial Waste Pond is removed.

Owing to the complexity of the hydrogeology of the Headquarters Area, the assessment of pumping rates that can be sustained without intercepting water from the mounds under the Sewage Lagoon and the Industrial Waste Pond can best be made using analytical or numerical techniques that are beyond the scope of this study. Such techniques could be used with existing data, but the reliability of the results could be greatly increased with data from the addition of monitoring wells located between the producing wells and the source areas. These proposed "outpost" wells are shown in Figure 18.

5.5.2 TNT Washout/Laundry Pond Area

Interpretation of the analytical results obtained in the TNT Washout Pond Area must be prefaced by a description of the processes causing the contamination. Based on the contamination matrix, [redacted] the [redacted] and [redacted] of these two explosives. Figure 19 shows the location of the series of washout ponds and laundry effluent holding ponds, the direction of ground-water flow, the direction of surface water flow, the extent of flooding during washout pond operation, and the location of Wells N-3A and N-3B.

Past explosive washout procedures generated effluent which was allowed to flow northward through the series of washout ponds. Periodic flooding and overflow of these ponds deposited explosive-laiden waters within the flood area designated in Figure 19. Effluent from the Depot laundry in the reported amounts of 7200 gallons per day is piped to the laundry effluent holding ponds identified in Figure 19. Laundry effluent is currently flowing into the western-most of these ponds. The overflow from these ponds originally flowed to the northwest, but presently flows to the northeast. The date that this change occurred is unknown. This overflow entrains explosives from the contaminated surface and underlying soil and continues to flush them down to the ground-water table.



TNT WASHOUT AND LAUNDRY EFFLUENT PROBLEM AREA

FIGURE 19

The extent of explosive contamination in this area is dependent upon the explosive content of effluent waters, the volumes of water discharged, the extent of areal flooding, and specific properties of the contaminant explosives. Ground-water contamination has occurred by the downward percolation of explosive-laiden waters through the soil column to the water table which is located at a depth of approximately 250 ft. Processes controlling this rate of explosive compound migration include aqueous solubility, volatibility, oxidation, hydrolysis, photolysis, sorption by soil constituents, and microbiological transformation. Recent research has shown that the processes of oxidation, reduction, and volatilization are relatively unimportant in controlling the migration of 2,4,6-TNT and RDX in the environment. The relative importance of the other processes is dependent upon specific site conditions. These conditions include ambient temperature, retention time of aqueous solutions on the surface (in ponds), the composition of sediments, and the depth to ground water.

Aqueous concentrations of TNT and RDX are controlled by their relatively low aqueous solubilities. The explosive 2,4,6-TNT has a solubility of 130 mg/l at 20°C, while RDX has a solubility of 60 mg/l at 20°C. These concentrations should be considered maxima as the kinetics of explosive compound dissolution would prevent these concentrations from being reached.

A review of recent literature showed that RDX is relatively persistent in the environment. In addition to aqueous solubility, photolysis (destruction by sunlight), biotransformation, and sorption by sediments, were established as controlling factors which govern the persistence of RDX in water. Of these control mechanisms, photolysis was found to most effectively remove RDX from the environment. In aqueous solution, and exposed to sunlight, RDX has a half-life of 1 to 14 days depending on seasonal and ambient air temperature conditions. Prolonged, direct sunlight yields maximum destruction efficiency. Photolysis of RDX yields formaldehyde, nitrite, and nitrate. Therefore, photolysis of RDX causes breakage of the ring structure. Once waters laiden with RDX have penetrated the soil surface the destruction of RDX ceases.

Numerous studies have shown that RDX is not susceptible to destruction by soil microbes. RDX showed no significant bio-transformation during a ten week period of experimentation. Addition of soil and culture nutrients did not affect the rate of RDX destruction. Some RDX destruction was observed in the presence of yeast under anaerobic conditions. Data from an Army depot in the northwestern U.S. shows that observed rates of migration for RDX are similar to migration rates for nitrate ions, indicating that RDX is not significantly attenuated by soil constituents. Therefore, once RDX reaches ground water, its migration is controlled only by ground-water flow velocity and hydrodynamic dispersion.

Nitroaromatic compounds also show appreciable destruction by photoysis. Photo-decomposition products of 2,4,6-TNT catalyze further 2,4,6-TNT destruction. Aqueous solutions of TNT exhibit a TNT half-life of one day, assuming 12 hours of sunlight per day. As with RDX this half life is dependent upon the season of the year and local climate. Destruction of TNT in washout ponds similar to those located at Tooele Army Depot is dependent upon the concentration of TNT in solution and the depth of sunlight penetration. Products generated during photolysis of 2,4,6-TNT are nitrate ions, nitrite ions, and methyl-based compounds such as methanol and formaldehyde. Photolysis does not appear to induce breakage of the benzene ring, so various aromatic compounds with nitrite and methyl groups would also be byproducts of TNT and toluene, and would evaporate from washout ponds leaving nitrated or methylated aromatic byproducts such as 1,3,5-TNB, 2,6-DNT, 2,4-DNT, and 1,3-DNB. Other reported photoproducts of 2,4,6-TNT include 4,6-dinitroanthranil, 2,4,6-trinitrobenzaldehyde, 2,4,6-trinitrobenzonitrile, and 2,4,6-trinitrobenzoic acid. Therefore, although 2,4,6-TNT appears to be more photo-active than RDX, it generates toxic byproducts while RDX photolysis is a more complete reaction.

Unlike RDX, 2,4,6-TNT exhibits significant biotransformation rates in the presence of soil microbes. Half-lives are on the order of 17 days with a lag time of approximately one month, allowing for microbe culture generation. Lag times were found to vary from 13 to 40 days with half-lives of 8 to 25 days depending on specific substrate/microbe conditions. Although 2,4,6-TNT shows relatively fast rates of biotransformation, the aromatic ring structure is not broken. Therefore, biotransformation products would be similar to photolysis products and the toxic nature of the local ground waters does not change as most by-products are non-volatile.

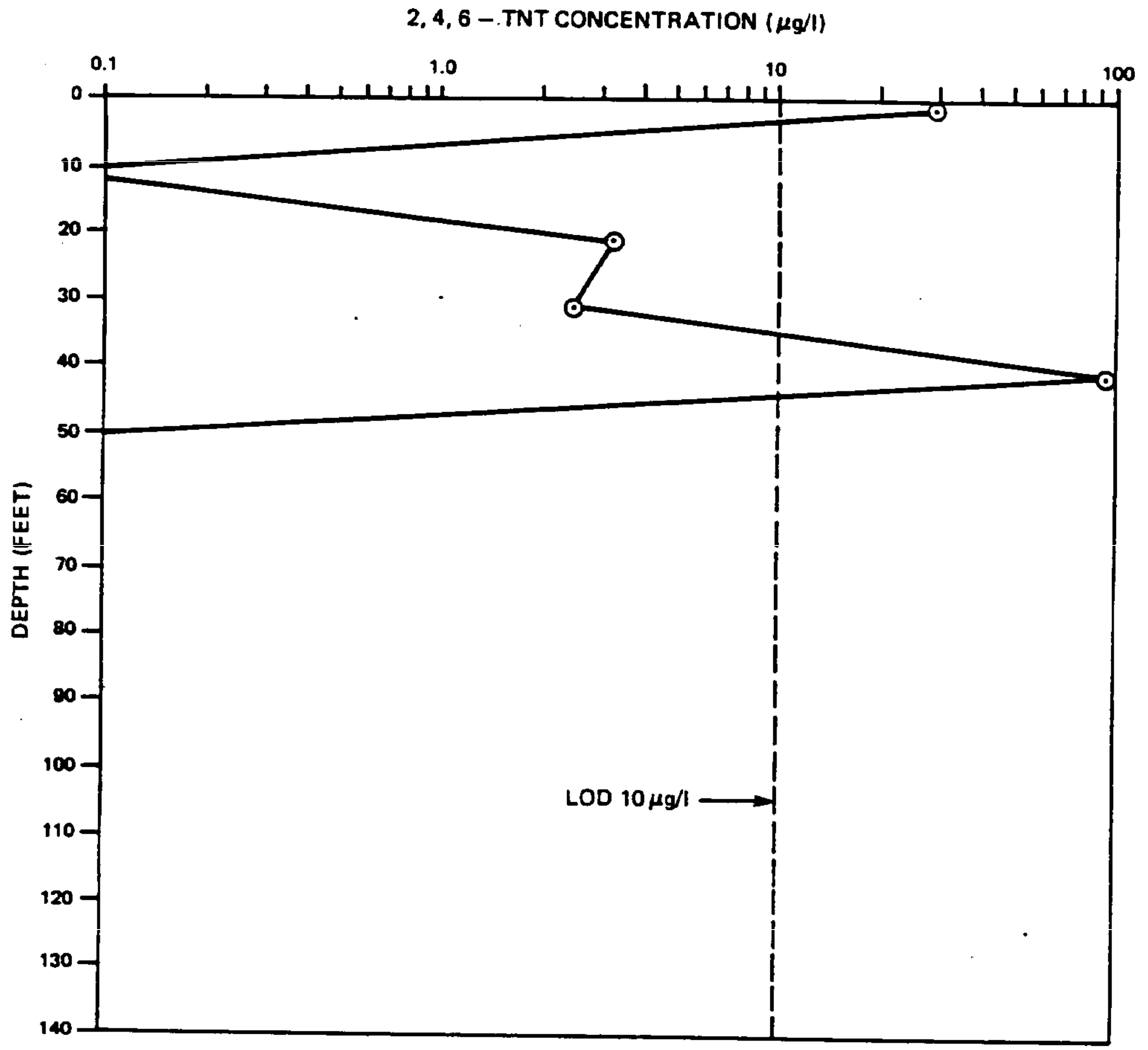
Migration of 2,4,6-TNT and its nitroaromatic byproducts is affected by attenuation by soil minerals. Nitroaromatic compounds are adsorbed by clay minerals by electrostatic attraction and the ability of these compounds to displace water present on the surface of clay particles. Analytical data from Savanna Army Depot confirm this high affinity that nitroaromatics have for clays, as shown by a natural clay layer at Savanna which has prevented migration of nitroaromatic compounds from flood plain TNT washout ponds. Nitrate ions from 2,4,6-TNT destruction are able to pass through this clay layer.

Data from this Army depot also suggest that 1,3,5-TNB is the first TNT degradation product in sandy soils, while nitrite groups are lost at a rate slower than methyl group loss. Data form an Army depot in the northwestern U.S. shows that while RDX migrates at rates similar to those of nitrate ions, 2,4,6-TNT migrates at approximately one-half that rate. This difference in transport rates is due to attenuation of 2,4,6-TNT and its nitroaromatic byproducts by soil constituents, primarily high surface-area clay minerals.

Soil concentrations of nitroaromatics and RDX from Well N-3A at Tooele Army Depot confirm migration rates found in the literature. Sediment samples were collected from this well at 10-foot intervals to a depth of 140 feet and analyzed for numerous organic and inorganic compounds including 2,4-DNT, 2,6-DNT, 2,4,6-TNT, Tetryl, and RDX. Detectable concentrations of all but Tetryl were found. Concentration profiles for 2,4,6-TNT, 2,4-DNT, and RDX are shown in Figures 20, 21, and 22 respectively.

High concentrations of all three compounds are found in the first few feet of sediment indicating that aqueous solubility and evaporation of surface water is controlling the downward movement of explosive compounds. Soil column lithology may also help retain explosive compounds on the surface as infiltrating water may be held in the top 8 feet of sediments above a silty layer long enough for evaporation to induce a net upward movement of soil moisture, forming an explosive-rich layer near the surface.

Upon examination of Figures 20, 21, and 22 it is evident that 2,4-DNT, a degradation product of 2,4,6-TNT is slightly more mobile than its parent compound. This slight increase in downward mobility is due to the absence of a



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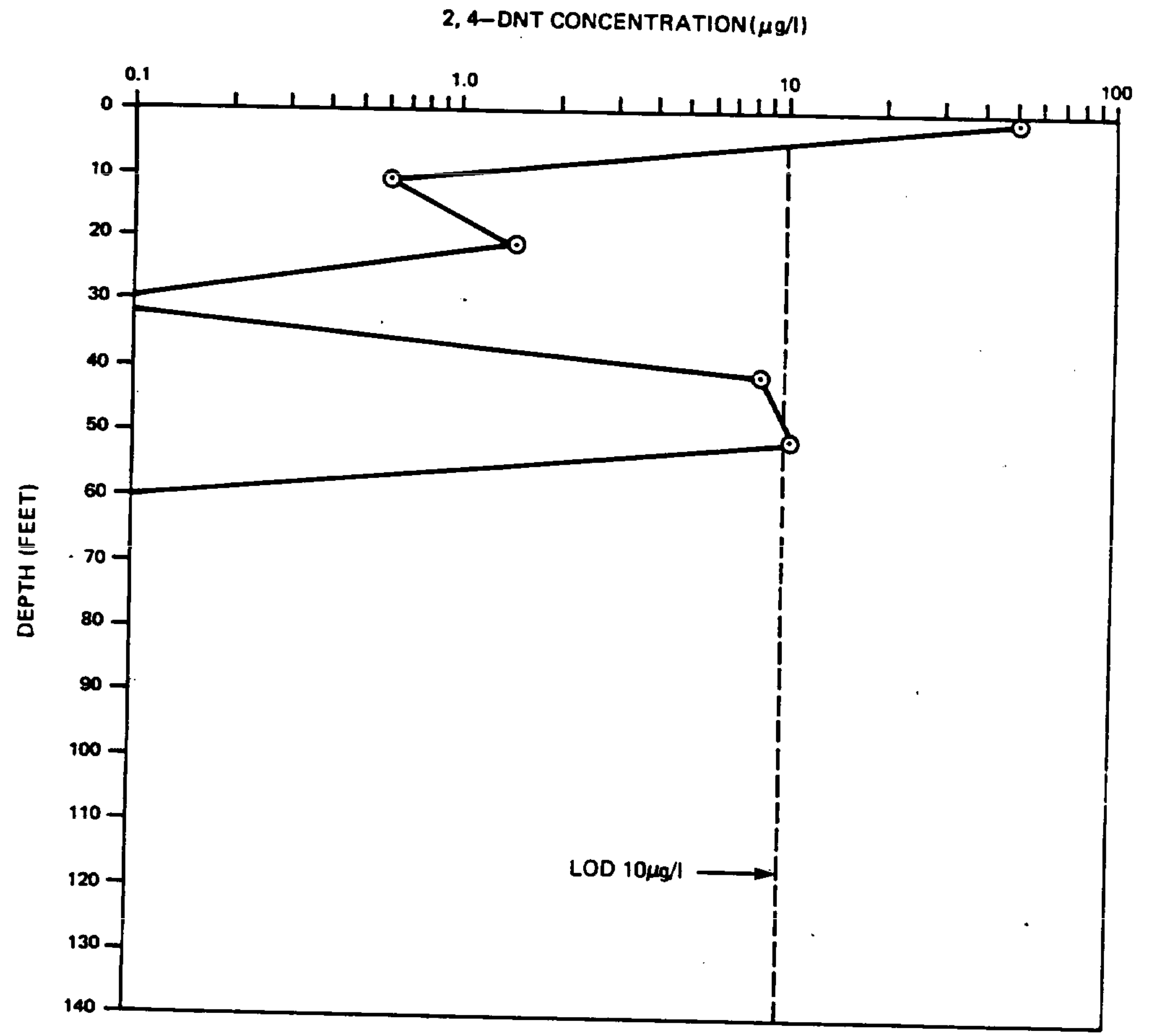
TOOELE ARMY DEPOT

2,4,6 - TNT CONCENTRATION
IN SOIL VERSUS DEPTH
WELL N-3A

7-82

FIGURE 20



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2, 4 - DNT CONCENTRATION
IN SOIL VERSUS DEPTH
WELL N-3A

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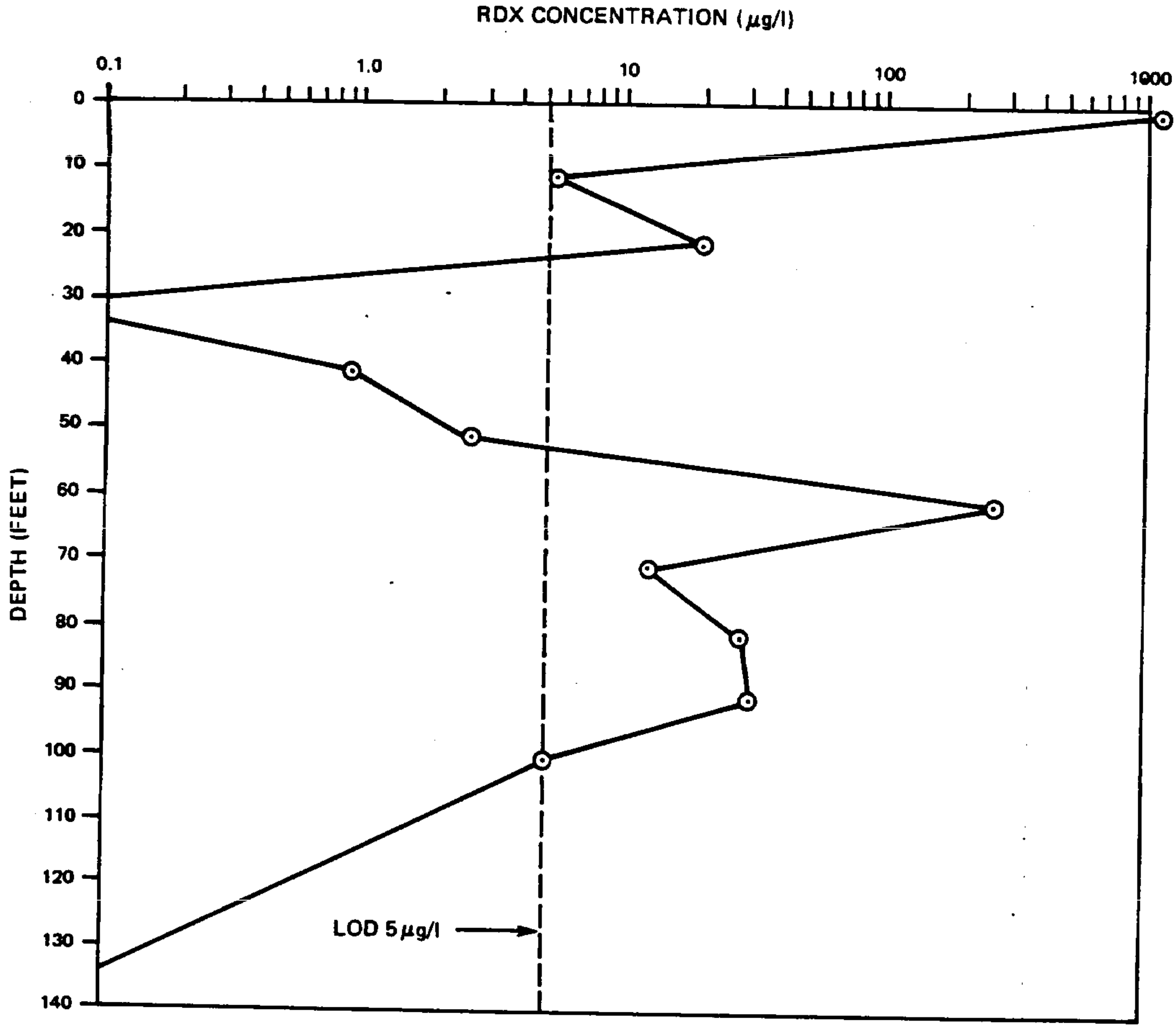
FIGURE 21



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TOOELE ARMY DEPOT

RDX CONCENTRATION
IN SOIL VERSUS DEPTH
WELL N-3A

7-82

FIGURE 22

single nitrate group, decreasing attenuation by soil minerals. Maximum concentrations in the soil at depth were found to be at 55 feet and 45 feet for 2,4-DNT and 2,4,6-TNT, respectively. A second smaller maxima was observed for both compounds at approximately 20 feet. This apparent "slug movement" of these nitroaromatic compounds may be a result of high TNT Washout Pond activity or periods of increased precipitation.

As was observed in several instances in the literature, RDX appears to migrate in soil environments at a rate approximately twice that of 2,4,6-TNT. High concentrations of RDX in the soil column are observed at 60 and 90 feet (Figure 22). RDX concentrations at the LOD of 5 micrograms per liter ($\mu g/l$) were observed as deep as 105 feet.

Analysis of sediment taken from the laundry effluent pond (N-SD3) shows no detectable explosive compounds but relatively high concentrations of sodium, sulfate, phosphate, and chloride. High concentrations of these constituents are to be expected in a laundry effluent. As these ions and salts of these ions are relatvely mobile in aqueous environments, significant total dissolved solids (TDS) will be contributed to the ground-water system by downward percolation of laundry effluent. However, lack of explosive contamination suggests that the laundry is not a source of TNT or RDX. This also suggests that the soil through which seepage from the Laundry Ponds moves is not contaminated with TNT and RDX, and that the perched zone under the Laundry Pond does not extend under the TNT Washout Ponds.

In conclusion, contamination by TNT, RDX, and degradation byproducts has occurred by downward percolation of TNT Washout Pond water. Flooding of these ponds has caused a greater extent of soil contamination, although it appears in flood areas that explosive compounds have not yet reached the water table. This conclusion is based solely on data from Well N-3A. Slugs of contamination from past washout activity may have already reached the ground water and are migrating beyond the immediate area. Two wells, shown in Figure 19, have been proposed to determine this possibility and to define contaminant penetration of the soil in the flooded area shown in the figure.

Both TNT and RDX are degraded by photolysis, at a relatively fast rate. While RDX breaks down to formaldehyde and nitrate ions, photolysis is not capable of rupturing the aromatic ring of TNT. Therefore, TNT degrades only to other aromatic compounds. Biotransformation of TNT and its nitroaromatic degradation products yields similar results as microbial action although it is not capable of breaking the aromatic ring. However, demethylation and denitrification of 2,4,6-TNT does occur in soil environments. Biotransformation of RDX does not appear to occur to any significant extent. Finally, data from Well N-3A confirms literature evaluations for the migration of TNT and RDX. In the soil column at Well N-3A, RDX appears to have migrated at a rate twice that of TNT. Retention of TNT by clay minerals is the probable mechanism for this difference in transport rates.

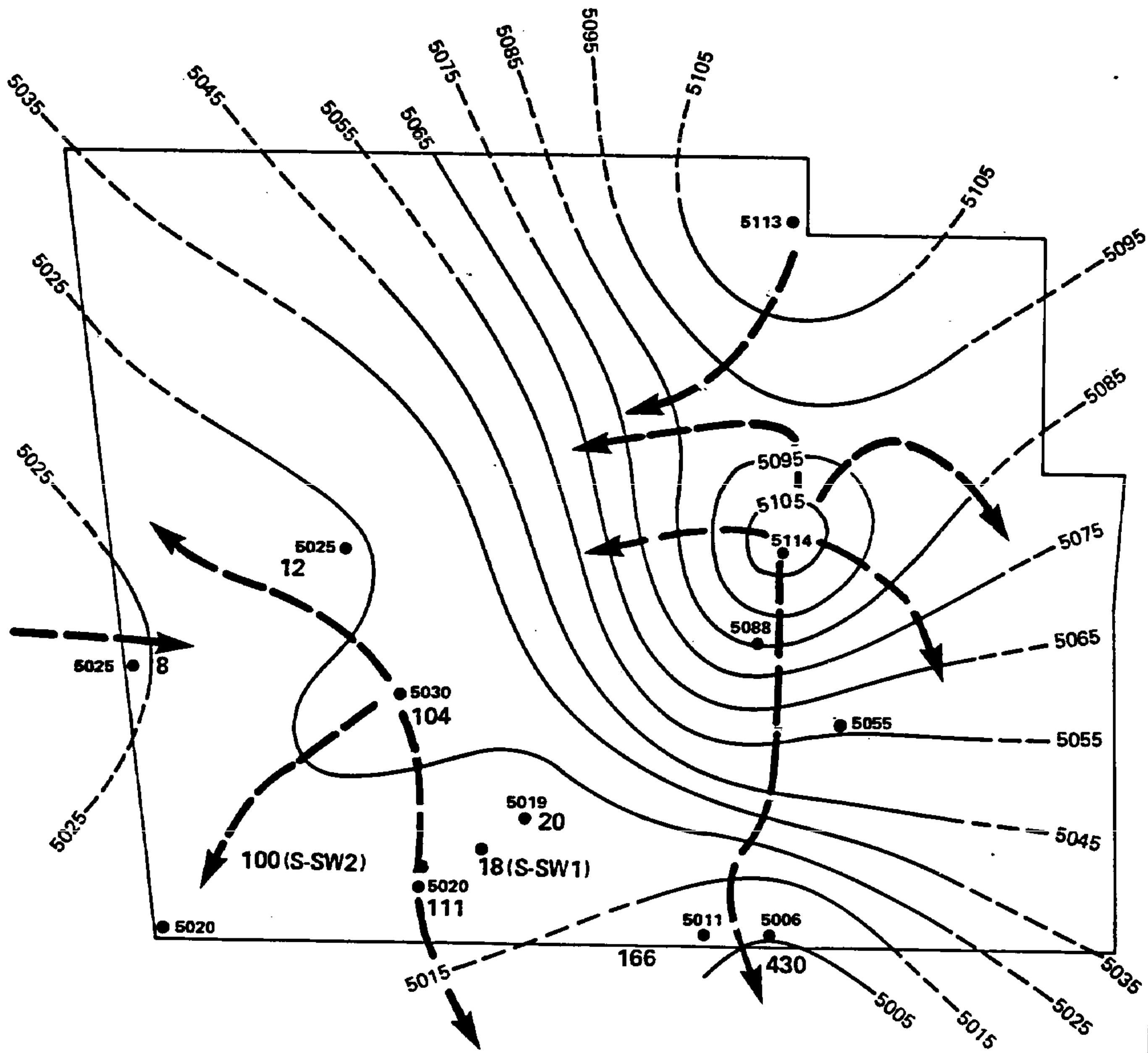
It has been calculated that travel time along the ground-water flow path from the TNT washout area to the Depot north boundary is approximately 125 years from the time contaminants first reached the water table.

5.5.3 Arsenic Contamination, South Area

Portions of the South Area of the Tooele Army Depot have relatively high concentrations of arsenic in the ground water of the upper aquifer. Ground water in the south-central part of the site has especially high arsenic levels, up to 430 μg/l in Well S-4. Utah Water Quality Standards limit the arsenic concentration in drinking water to 50 μg/l, while EPA standards are as low as 22 μg/l for arsenic. Since ground-water flow is south across the southern boundary of the Depot, it is certain that arsenic is migrating across the Depot boundary. Figure 23 shows the potentiometric head and flow lines with the corresponding concentrations of arsenic found in ground- and surface-water samples above the LOD of 7 μg/l. Wells S-4, S-5, and S-12, which were drilled immediately up-gradient hydrogeologically from the southern boundary, have arsenic concentrations of 430 μg/l, 166 μg/l, and 37 μg/l, respectively, as shown in Figure 23. In addition, arsenic has been found in soil and sediment samples in concentrations above the EPA standard. Sediment sample S-SD4, taken in the northwest corner of the Depot, has an arsenic concentration of 31 μg/l; soil samples from Well S-1 and boring S-8 have up to 98 μg/l arsenic.

The source of the arsenic contamination is not known. It is probably too widespread to be from a single limited source. It is possible that the high levels on the south boundary, topographically and hydrogeologically downgradient of the Demilitarization Area/Disposal Pits, are due to an unrecorded incident of Lewisite (an arsenic-bearing blistering agent) or other agent disposal. Records show only that Lewisite has been stored on the Depot for a limited time and in relatively small amounts.

No arsenic was detected in Well 3, the old CAMDS supply well, while a high concentration was detected very close-by in the soil (98 μg/l) and ground water (104 μg/l) of Well S-1. Since these wells tap different aquifers, this indicates that arsenic contamination has not yet reached the deeper, more prolific aquifer. In addition, no contamination was found in S-SW3, the CAMDS facility effluent.



EXPLANATION

5075	WATER LEVEL ELEVATION, FEET
	DIRECTION OF FLOW
18	ARSENIC CONCENTRATIONS, μg/L

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PROJECT NO.: 82-160

TOOELE ARMY DEPOT

SOUTH AREA POTENTIOMETRIC MAP SHOWING ARSENIC CONCENTRATIONS FOUND IN WATER SAMPLES

FIGURE 23

No background data on naturally occurring arsenic levels have been found for Rush Valley or similar areas. The foothills and fan to the northeast of the South Area, between Ophir and Mercur, have been heavily mined just off the Depot boundaries. Field inspections by Ertec personnel have revealed the presence of large quantities of realgar (an arsenic sulfide mineral) in and about many of these mines. It is likely that much of the arsenic contamination may be the result of the naturally occurring arsenic carried by runoff from the foothills and fan, and deposited on the playa. Since this part of the playa is also a large discharge area, naturally occurring arsenic would be continually concentrated as water is evaporated or evapotranspirated.

5.6 Data Management

All required data from the installation of wells and borings, sampling of surface water, ground water, soils and sediment, and chemical analyses were entered into computer files in the USATHAMA Tier 1 file format. The method used to enter the data and to merge and edit files is described below.

Data from the field drilling program was recorded on field data sheets as described in the Technical Plan. Site type and site I.D. codes were assigned in the field. The field log sheets were transcribed to coding sheets in the Tier 1 file format. Data were entered into the GFD, GMA, and SAC record formats. The coding sheets were used as the basis for data entry onto Tier 1 files via IR Data Entry Program using the Tektronix 405 terminal system supplied by USATHAMA to both Ertec and UBTL. These files were stored on Tektronix cassette tapes.

All Tier 1 files on cassette were submitted to files in Ertec's Data Base Management System (DBMS) using the Tektronix System as a remote data entry station. All Tier 1 formats were preserved in the Ertec DBMS files. The DBMS was used to merge and edit the numerous small files resulting from the entry of geotechnical and chemical analyses data as it became available. This method was used because it afforded in-house control and backup of the contents of these files without relying on uncertain telephone data communications between Ertec, UBTL, and USATHAMA.

The files for chemical analyses originally contained a code indicating whether an analysis showed a compound to be less than or greater than the certified limit of detection (LOD). After semi-quantitative certification by UBTL, as described in Sections 5.1 and 6.2, the semi-quantitative values for all compounds found above the qualitative LOD were entered into the Tier 1 files by direct editing to these files as they resided in Ertec's DBMS.

All Tier 1 files that were maintained in Ertec's DBMS were backed up daily on 9-track magnetic tape, when changes had been made to any files during that day.

The merged, corrected Tier 1 files presently reside on 9-track tape for submission to USATHAMAs 1108 system as well as on Ertec's DBMS. Upon project completion and satisfactory acceptance at USATHAMA, Ertec files will be deleted.

6.0 LESSONS LEARNED

As the project proceeded, unforseen problems arose in laboratory procedures and methods, drilling and well installation, and data management. In addition, much was learned about the use and value of geophysical methods assessing hydrogeological conditions. These "lessons learned" are discussed in the following sections. They will provide USATHAMA with information which can be applied to future programs of a similar nature.

6.1 Geotechnical Lessons Learned

The following summarizes significant lessons learned about the geotechnical aspects of the contamination study at TEAD.

1. In the subsurface environment at TEAD, the cable tool was at times a more efficient method of drilling, sampling and well installation than mud rotary. This was particularly true where cobble zones existed that resulted in excessive losses of drilling fluids, and where caving of surface materials presented hazards to drilling.

2. Drilling and well installation with a hollow stem auger to depths greater than 40 feet was more efficient when the initial drilling and sampling was done with a 6-inch auger and the hole reamed with a 10-inch auger for well installation. When caving was not a problem, casing could be installed directly in the 6-inch open hole.

3. Gravity and seismic refraction geophysical methods are a cost-effective means to delineate complex subsurface conditions such as those found in the eastern half of the TEAD North Area. The use of these methods requires control established by wells and borings.

4. Electrical resistivity was not successful in delineating perched groundwater zones or contaminated zones because insufficient resistivity contrasts exist in the subsurface at the sites surveyed.

5. The use of 4 1/2 inch casing simplified the sampling of wells for contamination. This casing size was used instead of 2-inch casing in anticipation of being able to perform aquifer tests on the screened zones by pumping, bailing, or injection.

6. The implementation of the drilling program during the winter and early spring months resulted in severe field conditions. Access problems caused by snow and mud resulted in a large amount of standby time for drilling subcontractors and field personnel. An estimated one-fourth of the cost for the drilling subcontractors could have been saved if the drilling and well completion had been accomplished during summer and fall.

7. The transmission of data files to USATHAMAs Tier 1 files was more efficiently accomplished by first merging the many small data files resulting from the use of the IR Data Entry Program, editing the merged files, and submitting the merged files to USATHAMA on a 9-track tape. Reliable submission over telephone lines to Tier 1 files was impossible owing to poor communication lines. The merging and editing procedure was more efficiently done on Ertec's in-house Harris 800 computer system than on the Univac 1108 system at USATHAMA.

6.2 Chemical Analysis Lessons Learned

Both during the qualitative certification process and the sample analyses, UBTL modified standard USATHAMA procedures when necessary to enhance the reliability and accuracy of analytical results. In this section, problem areas are discussed and recommendations offered from the point of view of the laboratory.

6.2.1 HPLC Methods for Explosives

During certification, it became necessary for UBTL to modify the two HPLC methods used for the analysis of explosives in water. The methods were 3S (Nitrotoluenes, Tetryl and RDX) and 6B (NG and PETN).

Method 3S as modified represents a useful analytical method, although the recoveries tend to be low. Method 6B as furnished to UBTL is not a very reliable analytical method. UBTL recommends that the normal-phase HPLC column be abandoned in favor of a reverse-phase column. The normal-phase (silica) column is very sensitive to traces of water while the reverse-phase (coated silica) column is not. UBTL has used a reverse-phase column for the analysis of NG for other projects since beginning this survey and has found that approach to be more reliable.

The following discussion concerns the differences between USATHAMA Method 3S and the modification in use by UBTL. The method outline is followed.

1) Application

Method 3S	UBTL Modification
NB, 2,4-DNT, 2,6-DNT, 1,3,5-TNB, 2,4,6-TNT, Tetryl, RDX and HMX in water	2,4-DNT, 2,6-DNT, 2,4,6-TNT, Tetryl and RDX in water

2) Tested Concentration Range

Method 3S	UBTL Modification
8 to 160 μg/l all analytes	1 to 5 μg/l all analytes

3) Sensitivity

Method 3S	UBTL Modification
Peak height 2.3 to 4.4 mm	1000 to 2000 integrator units

4) Detection Limit

Method 3S	UBTL Modification
8 μg/l all analytes	2,4-DNT - 2 μg/l 2,6-DNT - 3 μg/l 2,4,6-TNT - 2 μg/l Tetryl - 1 μg/l RDX - 1 μg/l

5) Interferences and Chemistry. The same for both Method 3S and the UBTL modification.

6) Analysis Rate

Ideally the analysis rate is the same for both methods. In the UBTL modification, it was expected that the use of a technician for sample preparation and the use of an autosampler for sample injection would offset the time required for extraction. The extraction step was incorporated into the method to achieve the detection limits of 1 μg/l for 2,4-DNT and less than 11 μg/l for the other analytes requested by USATHAMA. The methylene chloride extraction was based upon that described in USATHAMA Method 2B for the analysis of RDX in water. The solvent exchange step, as certified, satisfactorily removed from the standard water samples the methylene chloride which interferes with the analysis of RDX. However, some methylene chloride was retained in the field sample extracts after solvent exchange. It was necessary to add an inert gas purge step to the method to completely remove the methylene chloride from the sample extracts.

7) Instrumentation

Method 3S	UBTL Modification
Altex 312 MP gradient HPLC with 100 A pumps	Spectra-Physics SP-8700
injector (100 μl loop)	ternary solvent delivery system
LDC UV III detector	Waters WISP Model 710B
Varian 9176 recorder	autosampler
	PE Model LC 75 variable wavelength UV-visible detector

8) Parameters

	Method 3S	UBTL Modification
Column:	Spherisorb-ODS, 5 micron, 250 x 4.6 mm	Supelco RP-2, 5 micron, 250 x 4.6 mm
Solvent Program:	40%/60% methanol/water to 60%/40% methanol/water in 20 minutes	40% methanol/60% water, isocratic
Flow:	1 ml/min	1 ml/min
Detector:	254 nm at 0.032 AUFS	254 mn at 0.010 AUFS
Injection Volume:	100 μl	100 μl
Retention Times: 2,4-DNT	17.69 min	13.35 min
2,6-DNT	16.75 min	14.66 min
2,4,6-DNT	13.85 min	9.85 min
Tetryl	13.20 min	11.03 min
RDX	8.80 min	7.59 min

9) Hardware/Glassware, Chemicals and Reagents. The same for both Method 3S and the UBTL modification, except for the glassware and solvent used in the extraction by UBTL.

10) Calibration Standards

Method 3S	UBTL Modification
Standard Analytical Reference Materials (SARMS) weighed into the same flask and diluted out in methanol	Each SARM weighed out into a separate flask and diluted in menthanol. Aliquots combined to make up a stock standard.

11) Control Spikes

Method 3S	UBTL Modification
Methanol solution spiked into water	Methanol solutions spiked into water

12) Sample Preparation

Method 3S	UBTL Modification
Filter water samples before injection	Extract 500 ml of water with methylene chloride. Reduce volume using a K-D apparatus. Exchange solvent to methanol. Remove residual methylene chloride with an inert gas stream

13) Calibration and Sample Analysis

Method 3S	UBTL Modification
100 μl injected in duplicate	100 μl injected

In the next section, a comparison of USATHAMA method 6B and the UBTL modification is presented.

1) Application

Method 6B	UBTL Modification
NG and PETN in water	NG and PETN in water

2) Sensitivity

Method 6B		UBTL Modification
NG:	2.5 mm peak height for 23 ng	3300 integration units
PETN:	3 mm peak height for 19 ng	900 integration units

3) Detection Limit

Method 6B		UBTL Modification
NG:	5 μg/1	20 μg/1
PETN:	6 μg/1	5 μg/1

4) Interferences, Analysis Rate and Chemistry. The same for both Method 6B and the UBTL modification as certified. See the discussion in the Procedure section for the effect of field samples upon the analysis rate.

5) Instrumentation

Method 6B	UBTL
Perkin-Elmer 601 LC	Spectra Physics SP-8700
LC-55 variable wavelength detector	ternary solvent delivery system
	Waters WISP Model 710B auto-sampler
	PE Model LC-75 variable wavelength UV-visible detector
	Spectra Physics SP-4100 computing integrator

6) Parameters

	Method 6B	UBTL Modification
Column:	Waters radial compression column, 10 cm x 7 mm, 10 micron	Perkin-Elmer Silica A/10, 25 cm x 0.26 cm
Solvent:	2.5% isopropanol/97.5% hexane	0.3% isopropanol/99.7% isooctane
Flow:	2 ml/min	2 ml/min
Detector:	204 nm	204 nm at 0.02 AUFS
Injection Volumne:	175 μl	175 μl
Retention Times:	NG <10 min	6 min
	PETN <10 min	8 min

7) Hardware/Glassware, Chemicals and Reagents. Essentially the same for both methods, as well as Calibration Standards and Control Spikes. The calibration standards and control spikes are both stabilized with 2-nitrodiphenylamine in the UBTL modification.

8) Procedure

Method 6B

A 100 ml sample of water is swirled for at least one minute with 4 ml of methylene chloride (twice). The extracts are combined and dried in a stream of nitrogen. The residue is dissolved in 2 ml hexane and injected into the HPLC.

UBTL

A 100 ml sample of water, stabilized with 2-nitrodiphenylamine is shaken with 5 ml of methylene chloride for at least three minutes (twice). The extracts are combined and dried in a stream of nitrogen. The residue is dissolved in 2 ml of solvent (0.3% isopropanol/99.7% isooctane).

Discussion of Procedure

Though hexane can be used as an HPLC solvent at lower altitudes, at the altitude of Salt Lake City (approximately 5000 feet) it tends to form bubbles in the pump head. Therefore, the less volatile isooctane was substituted for hexane as a mobile phase solvent.

At USATHAMA's request, UBTL contacted the analytical laboratory Controls for Environmental Pollution (CEP) to discuss the analysis of explosives. It was recommended that the standards and samples be kept cool and protected from light. These recommendations were incorporated into the UBTL procedures.

The SARMs were supplied as acetone solutions. They were diluted in isopropanol according to Method 6B. The NG SARM solution was observed to be decomposing; that is, the chromatograms showed an NG peak of decreasing intensity and two additional peaks of increasing intensity. The integrity of the PETN solution also was suspect. With the concurrence of USATHAMA, NG and PETN standards were procured from manufacturers in the area. The chemist who supplied the NG standard suggested the use of an amine stabilizer. It was found that the stabilizer was needed in the water samples as well as in the solutions of standards. The use of the stabilizer was begun with the concurrence of USATHAMA.

Two problems arose with the analysis of field samples. Severe emulsions formed during the extraction of the field samples. Additional time was required to break the emulsions. The field samples contained impurities which required frequent washing of the column during the analysis of a set. These problems have increased the sample analysis time.

9) Calculations. Essentially the same for Method 6B and the UBTL modification.

6.2.2 Preservation of NG & PETN Samples

As noted in the above discussion of Method 6B, the decomposition of nitroglycerin (NG) was observed in stock solutions and in control samples. UBTL discussed this matter with Mr. Robert Baczuk of Hercules, Inc., a major manufacturer of NG. Mr. Baczuk is the chemist responsible for monitoring the aging of NG products after manufacture. It was his opinion that the NG decomposes in the presence of traces of acid to 1,3-dinitroglycerin and 1,2-dinitroglycerin as well as acidic products which perpetuate the decomposition. He recommended an acid-scavenger, 2-nitrodiphenylamine, as a preservative. This recommendation was incorporated into the UBTL sample handling and analysis procedures, after concurrence by USATHAMA.

6.2.3 Modification of the Soil Wetting Volume Determination

The Solid Waste Leaching Procedure (SWLP) soil wetting determination requires a knowledge of the soil density at the site. The soil sample is compacted to that density in the laboratory and the wetting volume is determined by percolation. The first soil samples were received in the laboratory without values for their in-situ densities. The laboratory was advised to use a density of 1.4 g/cc for gravelly samples, 1.4 to 1.45 g/cc for sandy samples and 1.55 to 1.6 g/cc for samples containing clay. The choice of which density to apply was subjective, allowing for the introduction of error. The samples were mostly clay. When compacted into a graduated cylinder to the indicated density, the percolation rate was quite slow, approximately 2-3 hours per 25 gram sample. Experimentation indicated a wetting volume of approximately 0.3 ml/g. Some further trials with the centrifuge approach indicated a similar value.

Allowing for a 50% error in determing the soil wetting volume (e.g., 0.45 ml/g rather than 0.3 ml/g), an overall error of 1.5% in the volume of water added to 100 grams of soil for leaching would be sustained. Considering the potential error of estimating soil density for the percolation approach, the small estimated overall error for the centrifuge approach, and the time savings of the centrifuge approach, the modification was suggested by UBTL and subsequently accepted by USATHAMA.

6.2.4 The Effect of Dissolved Solids Upon ICP Results

Some difficulty was encountered in the ICP analysis (Method 3T) due to the high concentration of dissolved solids in the samples. Utah water contains relatively high concentrations of dissolved material. The tenfold concentration step specified by the ICP method to enhance sensitivity also increased the concentration of other dissolved materials ten-fold. UBTL recommends that if an ICP equipped to handle solutions with high (up to 15% dissolved solids) is not available, atomic absorption analyses be used instead when it is likely that samples similar to those from Tooele will be analyzed.

6.2.5 Choice of Solvents for Extraction and Analysis

UBTL has consistently observed difficulties with pumping or injecting highly volatile solvents. This is attributed to the altitude of Salt Lake City. In two instances, substitutions of less volatile solvents were made.

Method 6B (NG & PETN in water) called for a 97.5% hexane/2.5% isopropanol mobile phase. The HPLC system developed bubbles while pumping the hexane. Therefore, isooctane which has the same polarity but a lower vapor pressure was substituted for hexane in the mobile phase.

Method 3W (Semi-volatiles by GC/MS) called for injection of the methylene chloride extracts into the GC/MS. The methylene chloride leaked from the autosampler syringe, making uniform injections impossible. At the last stage of concentration in the Kuderna-Danish apparatus the methylene chloride was exchanged for chloroform which has a lower vapor pressure. Repeatable injections were then obtained.

6.2.6 Use of Amber Plastic Sample Bottles

High backgrounds of nickel and zinc were encountered in the graphite furnace (GF/AA) analysis for metals. This was traced to the amber plastic bottles used for the collection and storage of the samples. The USATHAMA cleaning procedure called for rinsing with 5% nitric acid. It was found that the background concentrations of nickel and zinc could be reduced to acceptable levels by rinsing with warm 50% nitric acid. A quick comparison test indicated that the common white (translucent) plastic bottles on hand in the laboratory did not contribute to the high background levels of nickel and zinc. UBTL recommends that USATHAMA specify translucent plastic bottles as sample containers, rather than just plastic bottles. USATHAMA may wish to consider recommending a rinse with warm 50% nitric acid rather than 5% nitric acid.

6.2.7 Recovery of Phosphate and Nitrate from QC Samples

UBTL noted satisfactory recovery of all six anions from standard water QC samples. However, a low recovery was observed for phosphate in the natural water QC spiked samples. Nitrite was recovered from the natural water QC spiked samples at very low levels or not at all. The nitrate concentration in the natural water QC spiked samples was not elevated. The nitrite/nitrate results suggest the presence of a mechanism which non-oxidatively removes nitrite from water.

6.2.8 Qualitative Analyses

The Exploratory Stage initially specified qualitative analyses for the screening phase. In retrospect, semi-quantitative results were found to be more desireable. From the point of view of the laboratory, there are two reasons to initially specify semi-quantitative analyses. First, the cost to certify is increased less than 50% by going from four levels (qualitative) to six levels (semi-quantitative) because instrument setup represents a significant fraction of the cost of running four or six samples. Second, it is necessary to run the quality control samples semi-quantitatively in order to control the analysis. The blind sample requirement in the USATHAMA Quality

Assurance Manual makes it necessary for the chemist to analyze all samples semi-quantitatively, since he does not know which ones are controls. Thus the laboratory must perform semi-quantitative analyses in order to report qualitative results. UBTL recommends that semi-quantitative analyses be specified for screening surveys. The laboratory effort is not much greater than for qualitative analyses and the results are much more useful.

6.2.9 Spiked Natural Water Samples

As noted in the quality control reports, the preparation of blind quality control samples using split field samples (natural water samples) is of limited value. For the Tooele Army Depot Survey, the natural water control samples were spiked at the detection limit as required. In several cases (sodium, chloride and sulfate, for example) the amounts of analytes present in the samples exceeded the amount of the spike by several hundred-fold. A spiked field sample yields the most information if the level of the spike is between one-half and twice the level of the analyte present. UBTL recommends that if natural water quality control samples are desired, they be spiked at an appropriate level during the analysis.